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The Fucales (Ochrophyta, Phaeophyceae) of the Island of Pantelleria (Sicily Channel, Mediterranean Sea): a new contribution

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Abstract

In the past, only a few studies were carried out on the marine vegetation of the Island of Pantelleria, reporting a high level of biodiversity in this island. However, the most recent study, performed about 20 years ago, documented a total loss of Fucales below ca. 12 m of depth and their substitution with morphologically simpler species. In the present study, the current presence and distribution of *Cystoseira* s.l. and *Sargassum* around the Island of Pantelleria were assessed, comparing the current data with the previous studies on the marine vegetation of this island. Through monitoring activities (both snorkelling and scuba diving), 19 taxa were recorded: seven belonging to *Cystoseira*, six to *Ericaria*, four to *Gongolaria*, and two to *Sargassum*. Comparing these data with the previous studies, it was highlighted that most of the species previously reported are still present on the island. Moreover, approximately 20 years after their documented disappearance, deep-water species such as *C. foeniculacea* f. *latiramosa*, *G. elegans*, *G. montagnei*, *G. montagnei* v. *compressa* and *Sargassum* cf. *acinarium* were recorded during this study, suggesting a natural recovery for these Fucales. We recommend that, in order to guarantee a long-term conservation of these fucalean populations, it would be useful to establish a marine protected area in the Island of Pantelleria.

Keywords

Biodiversity, brown algae, *Cystoseira*, *Ericaria*, *Gongolaria*, marine vegetation, *Sargassum*

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Introduction

The Island of Pantelleria is located in the Sicily Strait, 55 nautical miles (approx. 88.5 km) from Cape Granitola (Italy) and 39 miles (approx. 62.8 km) from Cape Bon (Tunisia), with a surface area of 83 km^2 and a morphology derived mainly from ancient volcanic activities (Bianchi and Acri 2003). The island is located in the Pantelleria Rift, the deepest part of the Strait of Sicily, and has an irregular elliptical shape with the longest axis NW–SE (Paladino et al. 1935). This island can be subdivided into two geomorphologically distinct areas: the SE area is elevated above the sea surface, while the NW area is lowland and hilly (Paladino et al. 1935). The SE rocky shore consists of high, jagged cliffs, steeply sloping to depths of 30–40 m, into a bottom with large boulders interspersed with coarse sand or gravel (Alongi et al. 2004).

The current knowledge of the marine biology of the Island of Pantelleria is based on a few studies, focusing mostly on marine botany (Giaccone et al. 1972; Barone et al. 1978; Calvo and Sortino 1979), which revealed a high level of biodiversity of the marine biota (Bianchi and Acri 2003). The most recent study on the marine vegetation of this island was performed by Alongi et al. (2004), who documented a total disappearance of *Cystoseira* s.l. species and their replacement with morphologically simpler seaweeds, such as *Dictyopteris polypodioides* (De Candolle) J. V. Lamouroux, *Halopteris scoparia* (Linnaeus) Sauvageau and *Womersleyella setacea* (Hollenberg) R. E. Norris, at depths below ca. 12. Alongi et al. (2004) suggested that the reasons of this loss could be an increase in seawater temperature and changes in deep circulation pattern.

Despite the high value and vulnerability of *Cystoseira sensu lato* (i.e., genera *Cystoseira* C. Agardh, *Ericaria* Stackhouse and *Gongolaria* Boehmer) and *Sargassum* C. Agardh species, data on the distribution and conservation status of these Fucales are surprisingly limited and ecological analyses for many areas are still rare (Mancuso et al. 2018). Due to the massive decline of these taxa in many Mediterranean areas (Cormaci and Furnari 1999; Thibaut et al. 2005; Serio et al. 2006; Tsiamis et al. 2013; Thibaut et al. 2015; Catra et al. 2019), there is an urgent need to assess in detail the current species distributions and the stressors threatening them (Mulas et al. 2020), particularly in islands where there is typically a high level of endemism. This is the case, for example, for *Ericaria sedoides* Neiva & Serrão, an endemic species of the African coasts of Algeria and Tunisia and the Island of Pantelleria (Colombo et al. 1982; Bouafif et al. 2014). The Sicilian Channel represents the eastern limit of its range (Colombo et al. 1982; Boudouresque et al. 1996) thus representing a geographical limit. Its relatively restricted range and rarity make it a vulnerable species justifying measures for its protection (UNEP-MAP-RAC/SPA 2012).

In consideration of this, the aims of this study were to assess the current occurrence and distribution of *Cystoseira* s.l. and *Sargassum* species around the Island of Pantelleria, approximately 20 years after the latest study on the macrophytobenthos of the island, comparing the current data with those of previous studies.

Methods

During the first week of July 2022, a monitoring activity was carried out around the Island of Pantelleria. In particular, eleven sites were examined, covering all sides of the island: Bue Marino, Kattibuale, Punta Spadillo, Gadir, Cala Tramontana, Cala Levante, Martingana, Scauri, Grotte Sataria, Kuddie Rosse and Arenella (Fig. 1). In the sites of Punta Spadillo, Cala Tramontana and Cala Levante, a total of four scuba dives (each of an average duration of one hour) was performed. The other sites were visually inspected by snorkelling (see Table 1). Unfortunately, it was not possible to carry out further scuba dives, due to adverse marine conditions.

Fucalean species were identified *in situ* and photographed using two underwater cameras Olympus TG-6 and TG-4. When species examination was impossible to obtain in the field, a few fragments of thalli (subsequently stored in the private collection of G.M.) were collected and identified in the laboratory according to Gómez-Garreta et al. (2001), Cormaci et al. (2012), Rodríguez-Prieto et al. (2013) and Blanfuné et al. (2022).

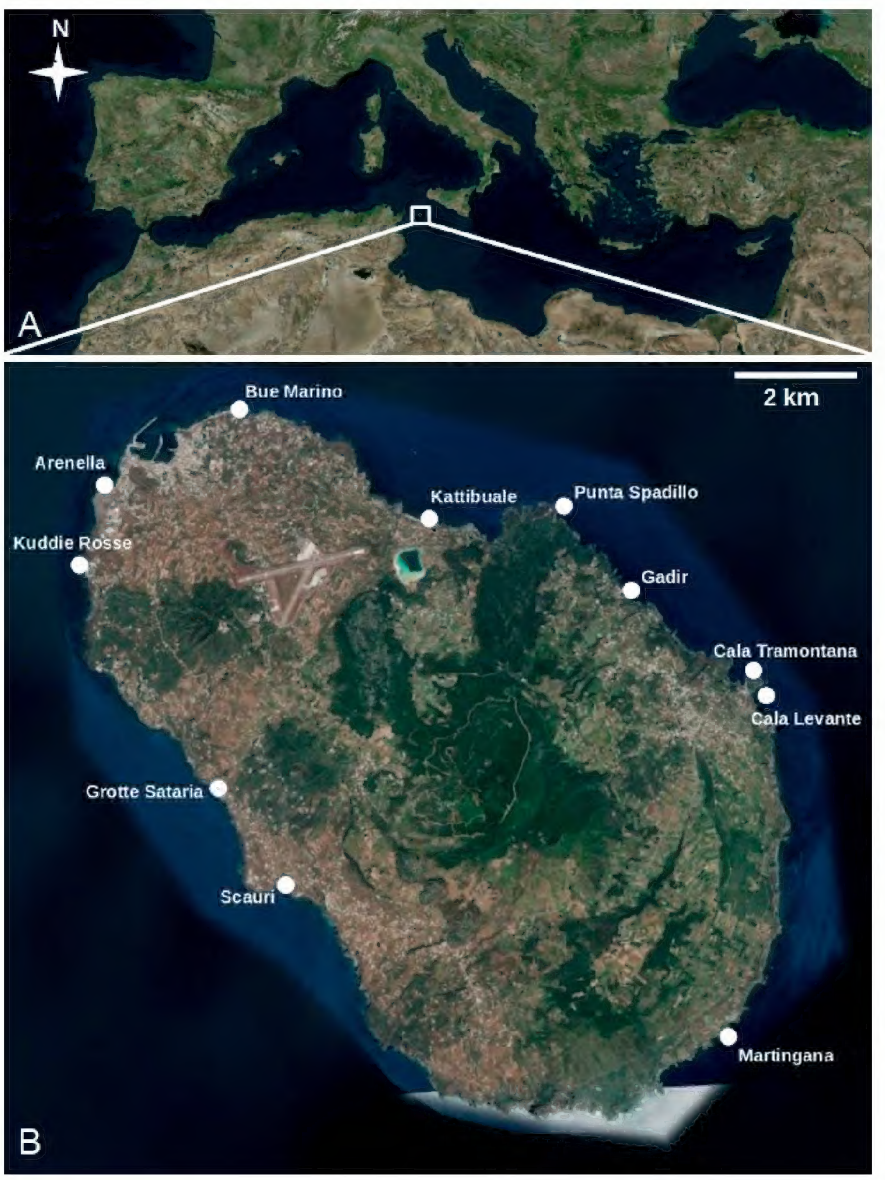

Figure 1. Island of Pantelleria **A** location of the island in the Mediterranean Sea **B** sites of the island investigated during this study.

Table 1. Detail of study sites, including GPS coordinates, dates and survey activities conducted during this study.

Site	Coordinates	Activity	Date
Bue Marino	36°50.5'N, 11°57.55'E	snorkelling	3rd July
Kattibuale	36°49.356'N, 11°59.436'E	snorkelling	4th July
Punta Spadillo	36°49.473'N, 12°0.843'E	scuba diving	4th July–5th July
Gadir	36°49.133'N, 12°1.9'E	snorkelling	5th July
Cala Tramontana	36°48.015'N, 12°2.943'E	scuba diving	4th July
Cala Levante	36°47.931'N, 12°3.163'E	scuba diving	5th July
Martingana	36°44.838'N, 12°2.676'E	snorkelling	8th July
Scauri	36°46.5'N, 11°57.15'E	snorkelling	9th July
Grotte Sataria	36°46.133'N, 11°57.25'E	snorkelling	7th July
Kuddie Rosse	36°48.908'N, 11°55.581'E	snorkelling	6th July
Arenella	36°49.77'N, 11°55.97'E	snorkelling	7th July

Results

During the monitoring activities, a total of 19 taxa was found: seven belonging to *Cystoseira*, six to *Ericaria*, four to *Gongolaria*, and finally two to *Sargassum*. The species and the sites where they were found are reported in Table 2.

Comparing our data with those previously reported by Giaccone et al. (1972), it is possible to note that 10 of the 18 fucalean species reported by these authors were also found during our monitoring activities (Table 3). On the contrary, the following taxa have not been observed: *Cystoseira platyclada* Sauvageau, *Ericaria zosteroides* (C. Agardh) Molinari & Guiry, *Cystoseira jabukae* Ercegovic, *Cystoseira humilis* Schousboe ex Kützing, *Gongolaria sauvageauana* (Hamel) Molinari & Guiry, *Cystoseira crinitophylla* Ercegovic, *Sargassum trichocarpum* J. Agardh and *Sargassum hornschuchii* C. Agardh.

Compared to the study by Alongi et al. (2004), only *C. humilis* was not recorded, while the other seven species identified by these authors were also found by us (Table 3).

For each species found during this study, we report below relevant information, including taxonomic and nomenclatural information (Basionym, Synonyms, Description, Habitat, Distribution, Remarks). The validity of the species names was checked by consulting Algaebase (Guiry and Guiry 2023).

Cystoseira compressa (Esper) Gerloff & Nizamuddin

Fig. 2A, B

Fucus compressus Esper, 1799. Basionym.

Cystoseira filicina Bory, *Cystoseira abrotanifolia* f. *fimbriata* Sauvageau, *Fucus fimbriatus* Desfontaines, 1799, *Cystoseira fimbriata* Bory, 1832. Synonyms.

Morphology of specimens from Pantelleria. This species is caespitose, attached to the substrate by a small discoid holdfast, from which several axes, both flattened and cylindrical, are issued, all devoid of spiniform appendages. The apices are tiny, smooth

Table 2. List of the species with their sampling depth found during the monitoring activity in the study sites: BM = Bue Marino; Kat = Kattibuale; PSpad = Punta Spadillo; Ga = Gadir; CTram = Cala Tramontana; CLev = Cala Levante; Mar = Martingana; Sca = Scauri; GSat = Grotte Sataria; KR = Kuddie Rosse; Ar = Arenella.

Taxa	BM	Kat	PSpad	Ga	CTram	CLev	Mar	Sca	GSat	KR	Ar
Range of depth	0–1 m	0–1 m	0–48 m	0–1 m	0–30 m	0–35 m	0–3 m	0–1 m	0–1 m	0–1 m	0–3 m
Cystoseira compressa	0–1 m	0–1 m	0–6 m	0–1 m	0–3 m	0–5 m	0–1 m	0–1 m	0–1 m	0–1 m	0–1 m
Cystoseira compressa f. *plana*	0.2–1 m						0.5–1 m				
Cystoseira compressa f. *rosetta*		0–0.5 m		0–1 m	0–0.5 m		0–1 m		0–0.5 m	0–0.5 m	0–1 m
Cystoseira pustulata			1–12 m		1–7 m	1–6 m	1–2 m			1 m	
Cystoseira foeniculacea						0.5–1 m				0.5–1 m	
Cystoseira foeniculacea f. *latiramosa*			20–30 m		18–22 m						
Cystoseira foeniculacea f. *tenuiramosa*						8–10 m					
Ericaria amentacea	0–0.2 m		0–0.2 m	0–0.2 m	0–0.2 m		0–0.2 m	0–0.2 m	0–0.2 m	0–0.2 m	0–0.2 m
Ericaria barbatula	0.5–1 m	0.5–1 m					0.5–2 m	0.5–1 m		0.5–1 m	0.5–3 m
Ericaria balearica	0.5–1 m		0.5–25 m		0.5–22 m	0.5–28 m		0.5–1 m	0.5–1 m	0.5–1 m	
Ericaria cf. *dubia*			40 m			35 m					
Ericaria crinita							1–3 m				0.5–2 m
Ericaria sedoides	0–1 m									0–1 m	0–1 m
Gongolaria barbata										0.5–1 m	1–2 m
Gongolaria elegans		1 m	1–15 m	1 m	1–8 m	1–12 m	1–3 m			1 m	1–3 m
Gongolaria montagnei			12–20 m		8–15 m	17–22 m					
Gongolaria montagnei var. *compressa*			28–35 m		26–30 m	33–35 m					
Sargassum cf. *acinarium*			30–45 m		28–30 m	32–35 m					
Sargassum vulgare	1 m	1 m	1–25 m	1 m	1–16 m	1–18 m	1–3 m	1 m	1 m	1 m	1–3 m

Table 3. Comparison of records of fucalean taxa obtained in this study with previous studies. x indicates that the species was reported previously; – indicates that the species was not reported; ? means that that the authors only indicated the genus.

Taxa	Giaccone et al. 1972	Alongi et al. 2004
Cystoseira compressa	x	x
Cystoseira compressa f. *plana*	–	–
Cystoseira compressa f. *rosetta*	–	–
Cystoseira pustulata	–	–
Cystoseira foeniculacea	–	–
Cystoseira foeniculacea f. *latiramosa*	x	–
Cystoseira foeniculacea f. *tenuiramosa*	x	x
Ericaria amentacea	x	x
Ericaria barbatula	–	x
Ericaria balearica	–	x
Ericaria cf. *dubia*	–	–
Ericaria crinita	x	–
Ericaria sedoides	x	x
Gongolaria barbata	–	–
Gongolaria elegans	x	–
Gongolaria montagnei	x	–
Gongolaria montagnei var. *compressa*	–	x
Sargassum cf. *acinarium*	x	?
Sargassum vulgare	x	?

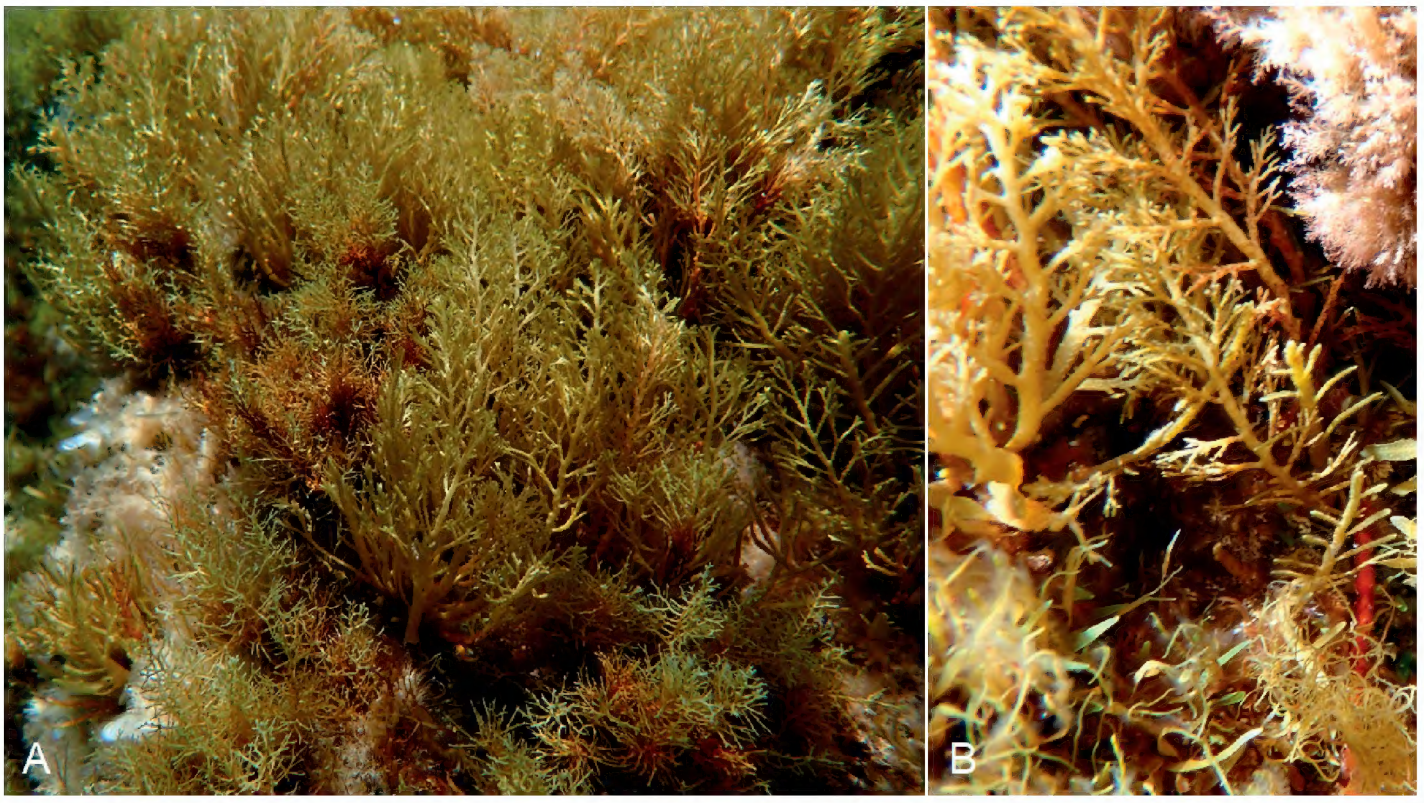

Figure 2. *Cystoseira compressa* **A** habit **B** detail of flattened branches with distichous-alternate disposal.

and not sharply protruding. Primary branches are generally flattened at the base, whereas they tend to be cylindrical at the apical parts. They are arranged distichously and alternating. Higher order branches can be flattened or cylindrical. In very sheltered environments this species shows numerous large isolate or grouped aerocysts. During the monitoring activities, this species was found fertile. Tiny lanceolate-fusiform receptacles are occurred in the terminal parts of branches. They were simple or branched and were located at the top of an aerocyst, to which they were connected by a small pedicel.

Habitat. *C. compressa* was found in all the inspected sites of the Island of Pantelleria, both during scuba dives and snorkelling activities. It was observed in the upper and middle infralittoral (from 0 to 6 m depth).

Distribution. This species is distributed in both the Atlantic Ocean (Nord-West Atlantic, Bermuda Islands and Nord-East Atlantic, from the Azores to Cape Verde) and Mediterranean Sea (Blanfuné et al. 2022).

Remarks. This species is quite common along the coasts of the island, where it is usually vicariant of *E. amentacea*.

***Cystoseira compressa* f. *plana* (Ercegovic) Cormaci, G. Furnari, Giaccone, Scammacca & D. Serio**
Fig. 3A, B

Cystoseira abrotanifolia subsp. *plana* Ercegovic. Basionym.

Morphology of specimens from Pantelleria. This form is caespitose with a pyramidal shape, attached to the substrate by a discoid holdfast. The apices are smooth and not

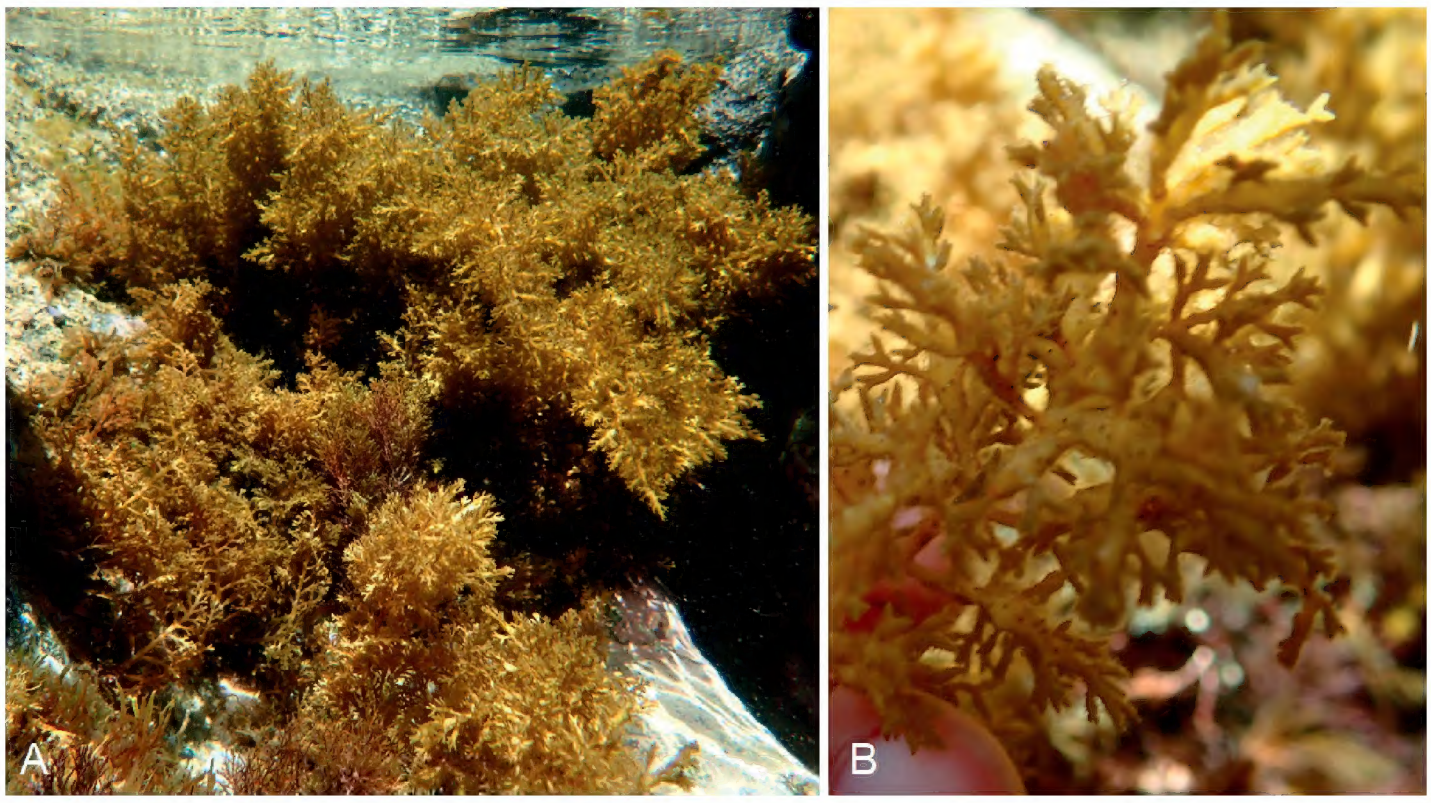

Figure 3. *Cystoseira compressa* f. *plana* **A** habit **B** detail of receptacles.

very protruding. All branches are flattened and arranged in a single plane with a distichous and pinnate disposal. They are crossed by a slightly protruding midrib, which is bordered by cryptostomata. During the monitoring activities, the thalli of this form were found reproductive. The receptacles are carried on terminal branches and are branched in a single plane.

Habitat. *C. compressa* f. *plana* was observed at Bue Marino and Martingana in shallow (0.2–1 m) and sheltered waters.

Distribution. This form has been recorded for Sicily, Adriatic Sea, Cyprus, Spain, Greece, Tunisia and Turkey (Blanfuné et al. 2022).

Cystoseira compressa f. *rosetta* (Ercegovic) Cormaci, G. Furnari, Giaccone, B. Scammacca & Serio

Fig. 4A, B

Cystoseira compressa subsp. *rosetta* Ercegovic. Basionym.
Cystoseira compressa subsp. *rosetta* Ercegovic. Synonym.

Morphology of specimens from Pantelleria. This form is cespitose, with flattened habit, forming a rosette. It is attached to the substate by a small discoid holdfast. The apices are smooth. Primary branches are short (1–4 cm), strongly flattened and foliaceous. They are usually crossed by brownish transversal stripes. The branches are arranged with a distichous and alternating disposal. The cryptostomata are not very prominent and are disposed on longitudinal series. During the monitoring activity, we did not find fertile thalli of this form.

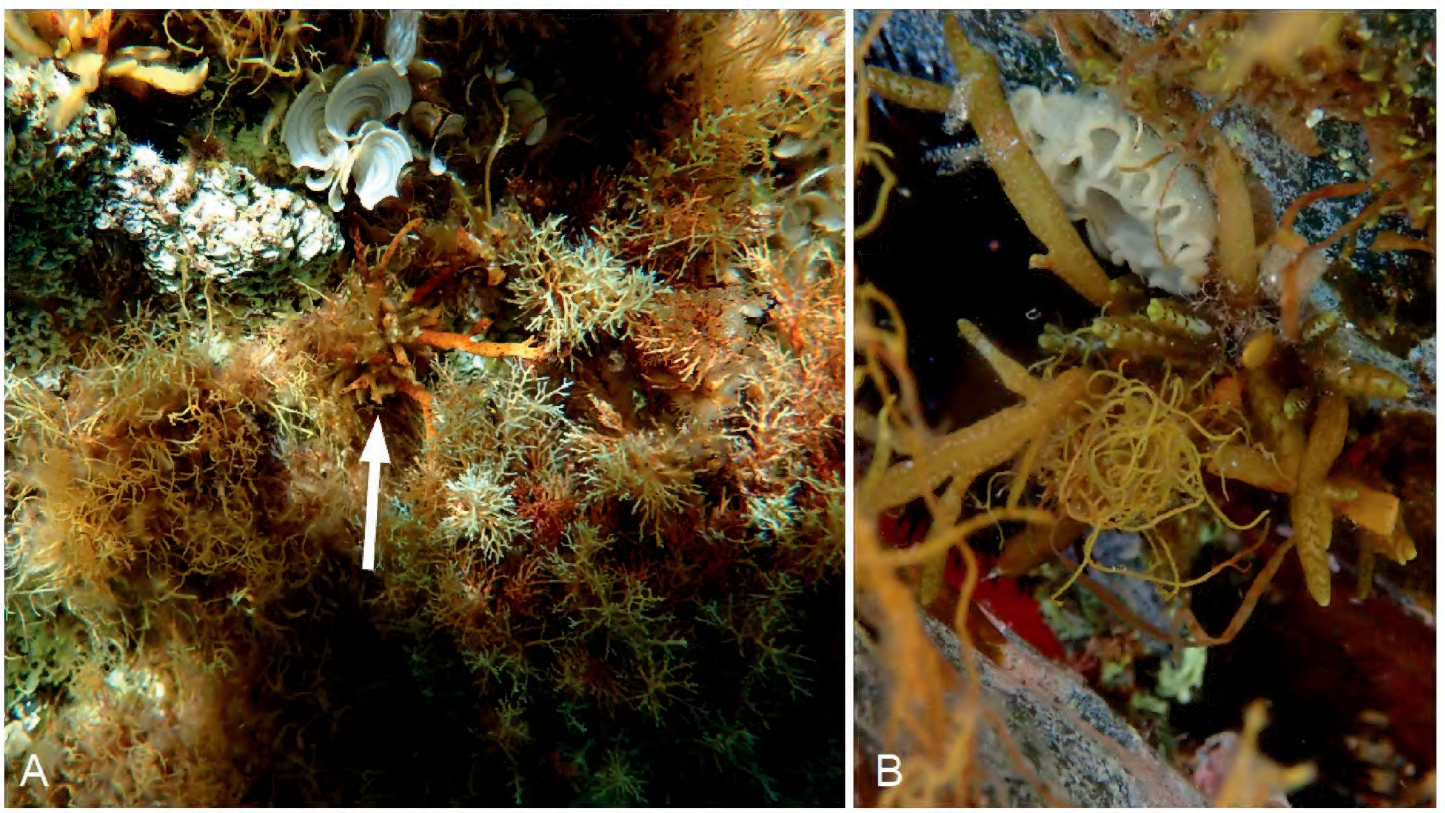

Figure 4. *Cystoseira compressa* f. *rosetta* **A** habit (the arrow indicates the thallus) **B** detail of primary branches with brownish transverse bands and cryptostomata disposed in longitudinal series.

Habitat. *C. compressa* f. *rosetta* occurred on wave-exposed coasts at Kattibuale, Gadir, Cala Tramontana, Martingana, Grotte Sataria, Kuddie Rosse and Arenella, in the upper infralittoral (0–1 m).

Distribution. It is distributed in the whole Mediterranean Sea and along the North-West Atlantic, Bermudas Islands and East Atlantic, from Azores to Cape Verde (Blanfuné et al. 2022).

Remarks. During the monitoring, thalli of this form were found isolated in shaded habitats, such as in small crevices between rocks.

Cystoseira pustulata (Ercegovic) Neiva & Serrão

Fig. 5A–C

Cystoseira abrotanifolia subsp. *pustulata* Ercegovic. Basionym.
Cystoseira compressa subsp. *pustulata* (Ercegovic) Verlaque. Synonym.

Morphology of specimens from Pantelleria. *C. pustulata* is a caespitose species, attached to the substrate with a small discoid holdfast. It has smooth apices, and cylindrical, thin and short axes. Primary branches are compressed, almost at the base, while higher order branches are cylindrical and always slender. This species bears protruding cryptostomata, which give it a pustulate habit. During the monitoring, this species was found fertile. The receptacles were borne in the terminal portions of the branches, fusiform in shape, isolated or rarely bifurcated.

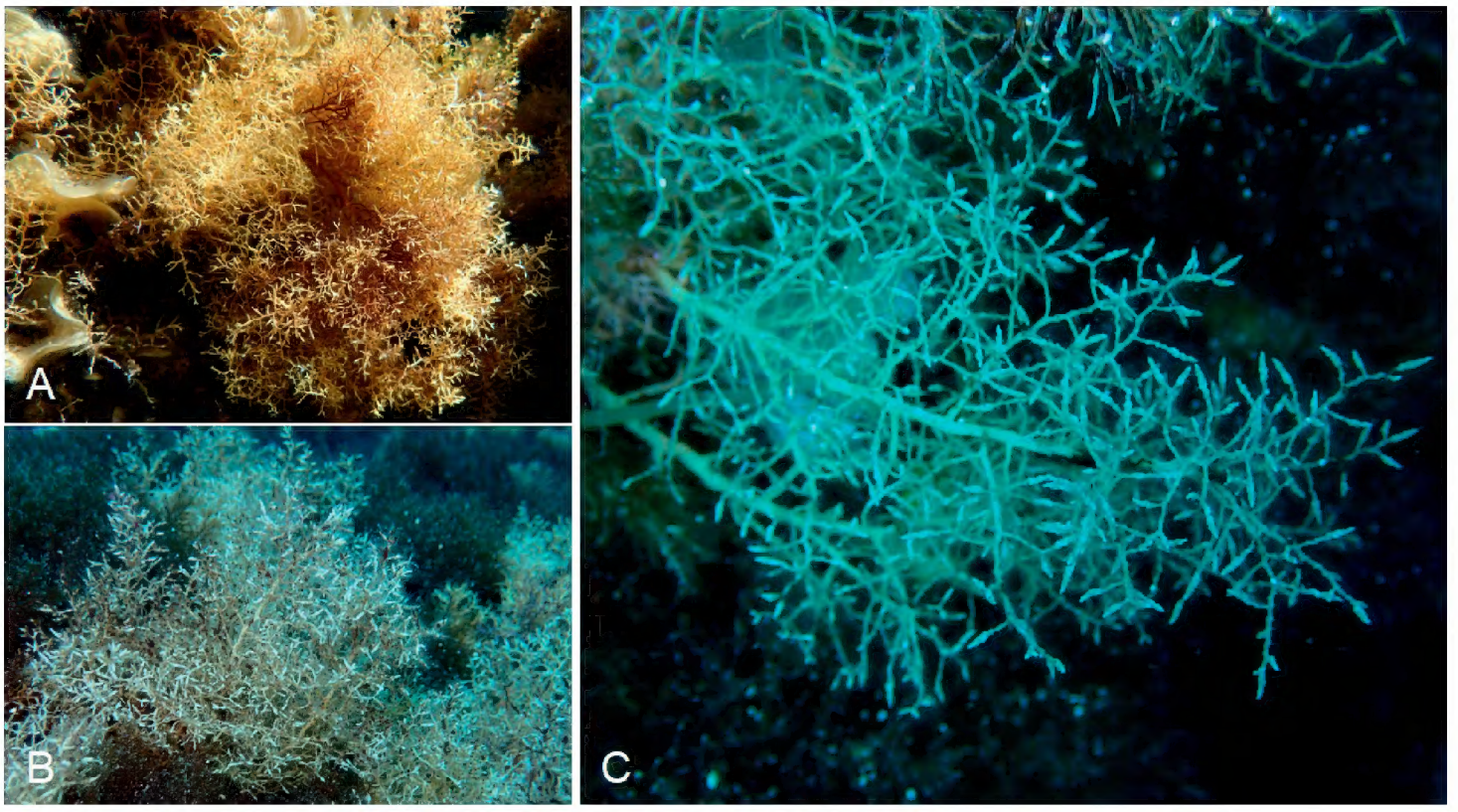

Figure 5. *Cystoseira pustulata* **A, B** habit **C** detail of receptacles.

Habitat. This species was found at Punta Spadillo, Cala Tramontana, Cala Levante, Martingana and Kuddie Rosse. It was detected during both snorkelling surveys and scuba dives, from the upper to the middle infralittoral (from 1 to 12 m depth).

Distribution. According to Neiva et al. (2022), who recently elevated it to species rank, *C. pustulata* is distributed in the Azores, Canary Islands, Spain, Italy, Malta and Greece.

Remarks. Some authors previously considered this species conspecific with *C. humilis* Schousboe ex Kützing. However, Neiva et al. (2022) demonstrated that *C. pustulata* is an independent species and reported it for Pantelleria. Therefore, we believe that the past records of *C. humilis* by Giaccone et al. (1972) and Alongi et al. (2004) might actually refer to this new taxon.

Cystoseira foeniculacea (Linnaeus) Greville

Fig. 6A–D

Fucus foeniculaceus Linnaeus. Basionym.

Cystoseira abrotanifolia (Linnaeus) C. Agardh, *C. concatenata* (Linnaeus) C. Agardh, *C. discors* (Linnaeus) C. Agardh, *C. ercegovicii* Giaccone, *Fucus abrotanifolius* Linnaeus, *F. barbatus* Linnaeus, *F. concatenatus* Linnaeus, *F. discors* Linnaeus, *Phyllacantha concatenata* (Linnaeus) Kützing. Synonyms.

Morphology of specimens from Pantelleria. *C. foeniculacea* is a caespitose species, with numerous axes that originate from an irregular discoid holdfast. The axes bear numerous small protuberances that give them a knotty habit. The apices are spinose

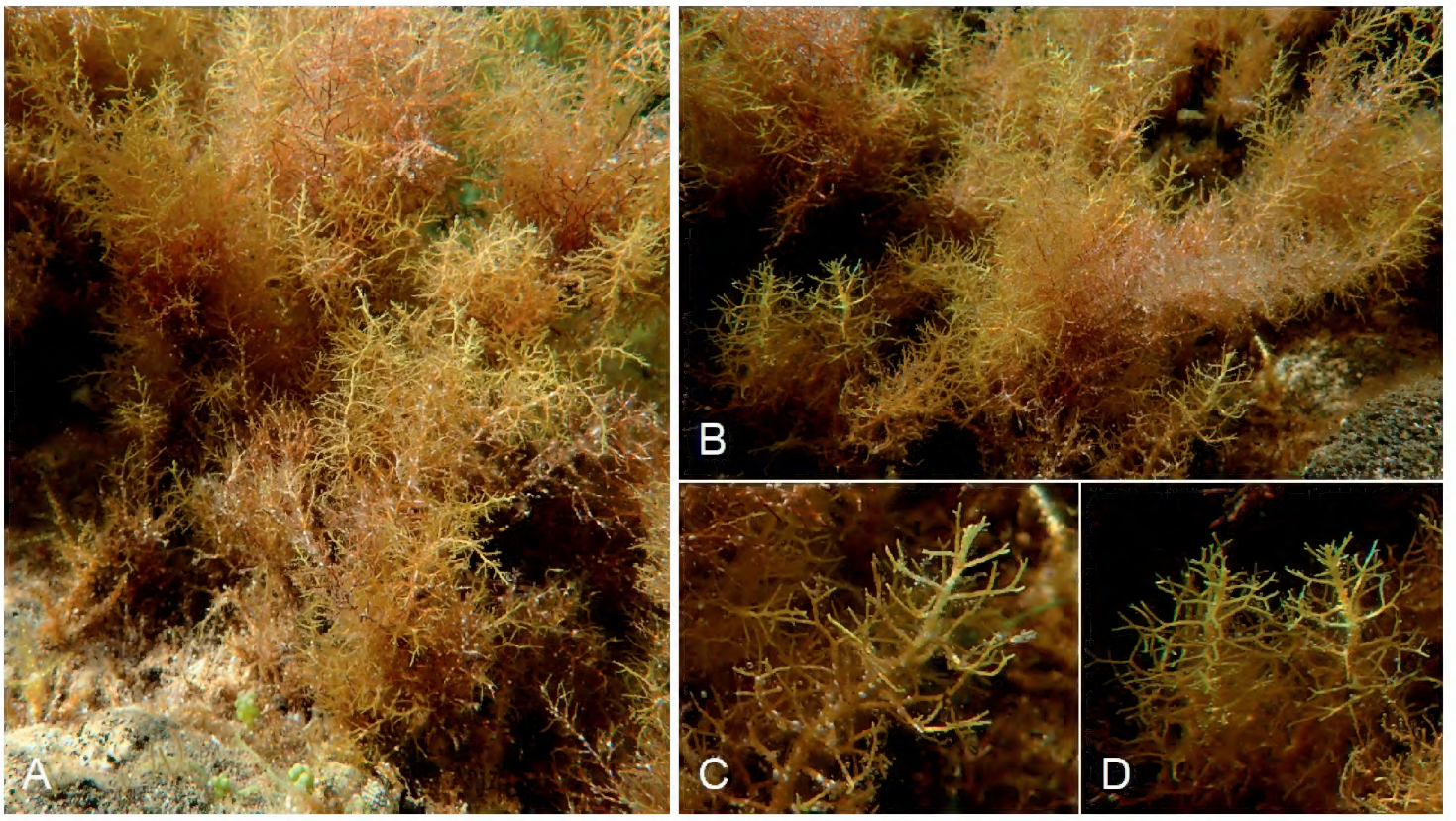

Figure 6. *Cystoseira foeniculacea* **A, B** habit **C, D** detail of axes with distichous branching.

and not sharply protruding. Axes can be flattened and branched distichously. Secondary branches can be flattened or cylindrical. Higher order branches are filiform, divaricate, alternating in several planes. During the monitoring activity, this species was not reproductive.

Habitat. This species was found in shallow (0.5–1 m) and sheltered habitats (as rock pools) partially covered by coarse gravel and cobbles at Kuddie Rosse and Cala Levante.

Distribution. The species is widely distributed in the Mediterranean Sea and occurs also in the Atlantic Ocean, from Scotland to Cape Verde (Blanfuné et al. 2022).

Cystoseira foeniculacea f. *latiramosa* (Ercegovic) A. Gómez Garreta, M. C. Barceló, M. A. Ribera & J. R. Lluch

Fig. 7A, B

Cystoseira discors subsp. *latiramosa* Ercegovic. Basionym.
Cystoseira ercegovicii f. *latiramosa* (Ercegovic) Giaccone, *Cystoseira schiffneri* f. *latiramosa* (Ercegovic) Giaccone. Synonyms.

Morphology of specimens from Pantelleria. This form is caespitose, attached to the substrate by an irregular discoid holdfast, from which cylindrical and knotty axes originate. The apices of axes are spinose. All branches are flattened, with a central midrib and toothed margins. Branching is sparse and distichous-alternate. During the monitoring activities, this species was found fertile. The receptacles are apical, lanceolate-fusiform, briefly pedicellate, isolated or branched.

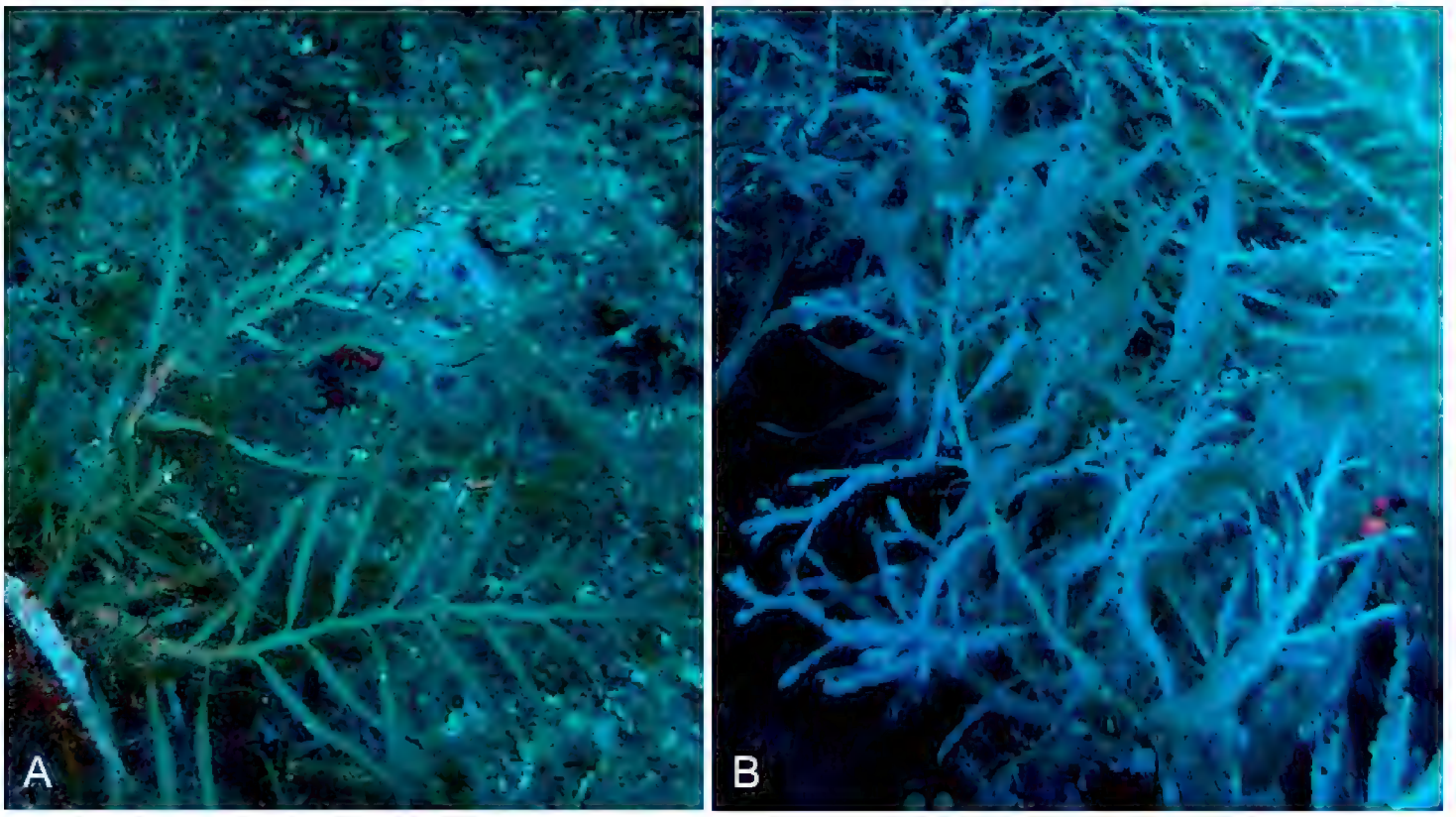

Figure 7. *Cystoseira foeniculacea* f. *latiramosa* **A, B** habit with knotty axes and flattened and distichous-alternate branching.

Habitat. *C. foeniculacea* f. *latiramosa* was observed during scuba dives at Punta Spadillo and Cala Tramontana, in deep waters (from 18 to ca. 30 m of depth).

Distribution. This form has been reported from Spain, Corsica, Tunisia, Malta, Italy, Adriatic, Greece, Cyprus and Turkey (Blanfuné et al. 2022).

Remarks. *C. foeniculacea* f. *latiramosa* is considered a rare seaweed in phase of regression (Rodríguez-Prieto et al. 2013), due to its distribution in deep environments, which are nowadays particularly subjected to trawling, pollution, deposition of marine litter, over-sedimentation, and competition with invasive alien species. Therefore, the record of this species in the waters of the Island of Pantelleria is particularly interesting and should receive special attention.

Cystoseira foeniculacea f. *tenuiramosa* (Ercegovic) A. Gómez Garreta, M. C. Barceló, M. A. Ribera & J. Rull Lluch

Fig. 8A, B

Cystoseira discors f. *tenuiramosa* Ercegovic. Basionym.

Cystoseira ercegovicii f. *tenuiramosa* (Ercegović) Giaccone, *Cystoseira schiffneri* f. *tenuiramosa* (Ercegović) Giaccone. Synonyms.

Morphology of specimens from Pantelleria. *C. foeniculacea* f. *tenuiramosa* is caespitose, fixed to the substrate by a discoid holdfast from which several cylindrical axes originate. The apices are prominent and spinose. Primary branches are cylindrical,

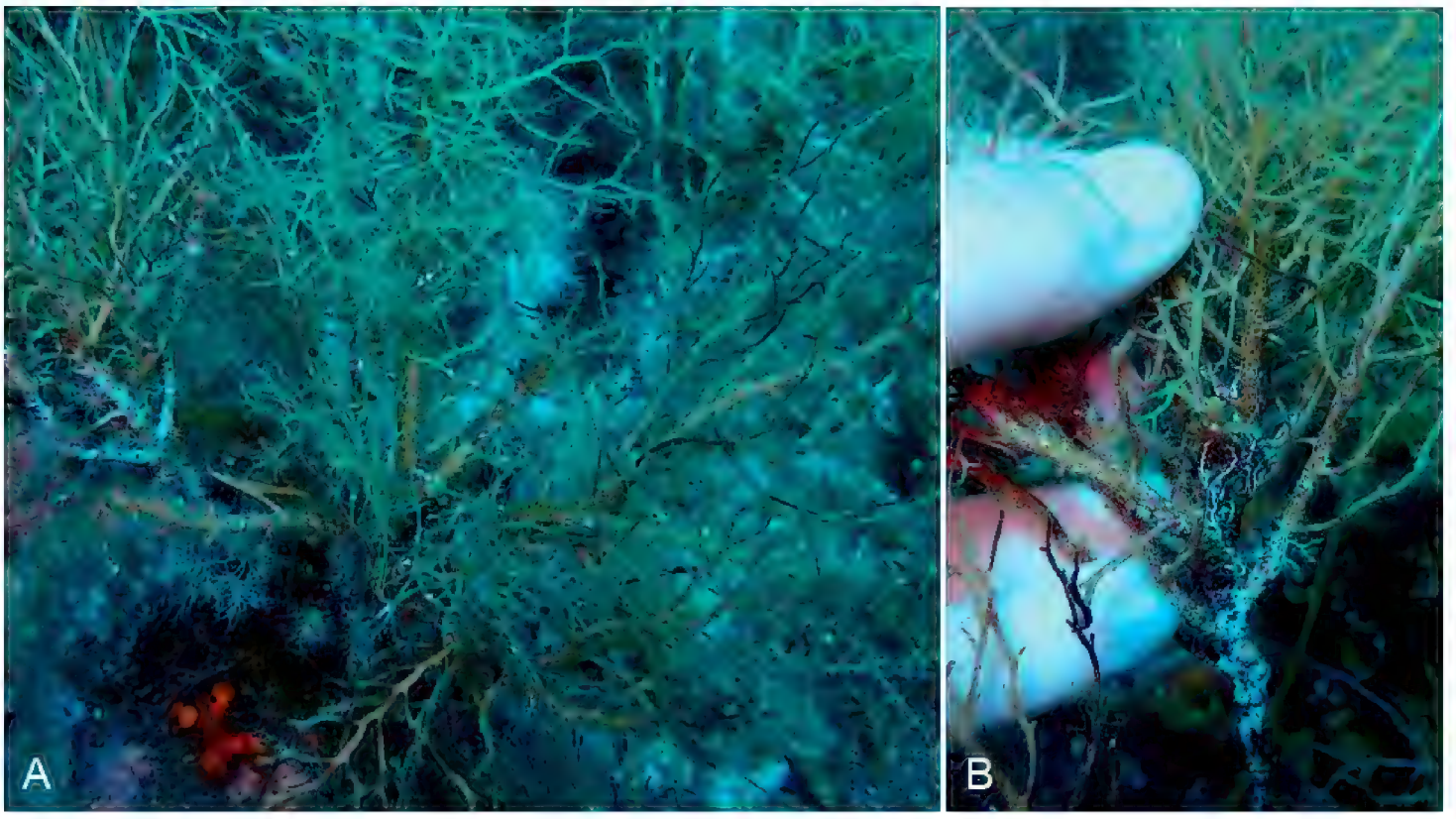

Figure 8. *Cystoseira foeniculacea* f. *tenuiramosa* **A** habit **B** detail of a prominent and spinose apex.

sometimes compressed, and knotty. Higher order branches are filiform, cylindrical and without spinose appendages.

Habitat. During the monitoring activities, this form was only observed at Cala Levante at 8–10 m depth.

Distribution. This form is distributed both in the Atlantic Ocean (Canary Islands) and in the Mediterranean Sea (Adriatic, Balearic Islands, Cyprus, Spain, France, Greece, Italy, Tunisia and Turkey) (Blanfuné et al. 2022).

Ericaria amentacea (C. Agardh) Molinari & Guiry

Fig. 9A–C

Cystoseira ericoides var. *amentacea* C. Agardh. Basionym.
Cystoseira stricta var. *amentacea* (Bory) Giaccone, *Halerica amentacea* (C. Agardh) Kützing, *Carpodesmia amentacea* (C. Agardh) Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *E. amentacea* is a caespitose species, fixed to the substrate by a robust crustose holdfast. *In situ* it shows a blue-violet iridescence, especially near the apices and young branchlets. The apices are spinose and not very prominent. The axes are cylindrical and short. All branches are covered by simple or bifid spinose appendages. During the monitoring activities, this species was found fertile. Receptacles are compact, terminal and spinose, with conceptacles present at the base of each spinose appendage.

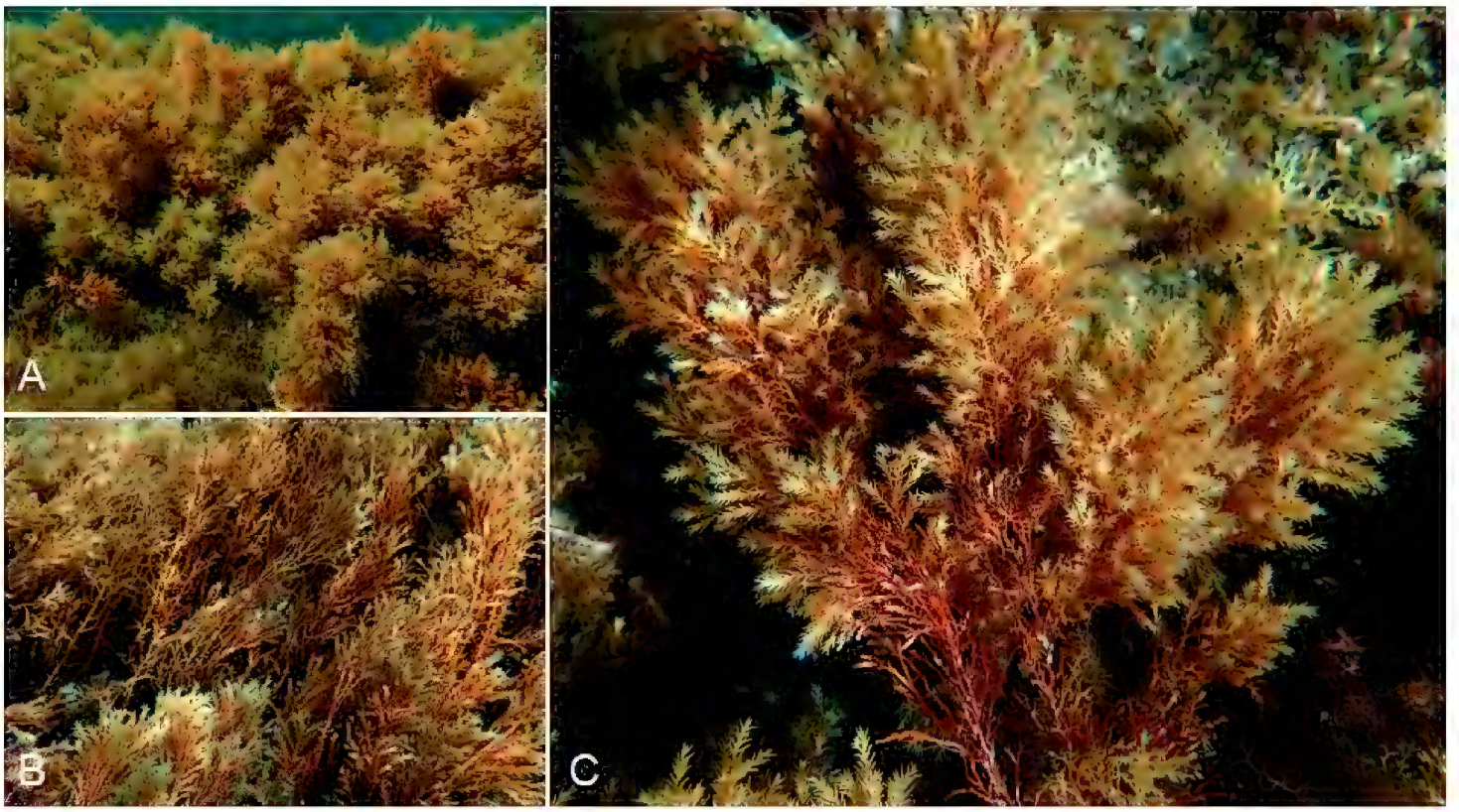

Figure 9. *Ericaria amentacea* **A, B** habit **C** branches with fertile receptacles.

Habitat. During the monitoring, this species was observed forming a continuous belt in the infralittoral fringe along exposed and semi-exposed coasts at Bue Marino, Punta Spadillo, Gadir, Cala Tramontana, Martingana, Scauri, Grotte Sataria, Kuddie Rosse and Arenella.

Distribution. According to Neiva et al. (2022), this entity falls within the *Ericaria selaginoides* complex haplogroup A, which is distributed in the Atlantic, south-eastern Iberian Peninsula, Balearic Islands and the Island of Pantelleria.

Remarks. Comparing the distribution reported by Alongi et al. (2004) with our data, the distribution of this species appears to have remained almost stable at the investigated sites.

Ericaria barbatula (Kützing) Molinari & Guiry

Fig. 10A, B, C, D

Cystoseira barbatula Kützing. Basionym.
Cystoseira graeca Schiffner ex Gerloff & Nizamuddin, *Carpodesmia barbatula* (Kützing) Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *E. barbatula* is caespitose, attached to the substrate by an irregular basal disc, from which several cylindrical, thin and blackish axes take origin. The axes are tuberculate for the presence of basal stumps of the fallen primary branches. The apices are strongly prominent and smooth. Primary and

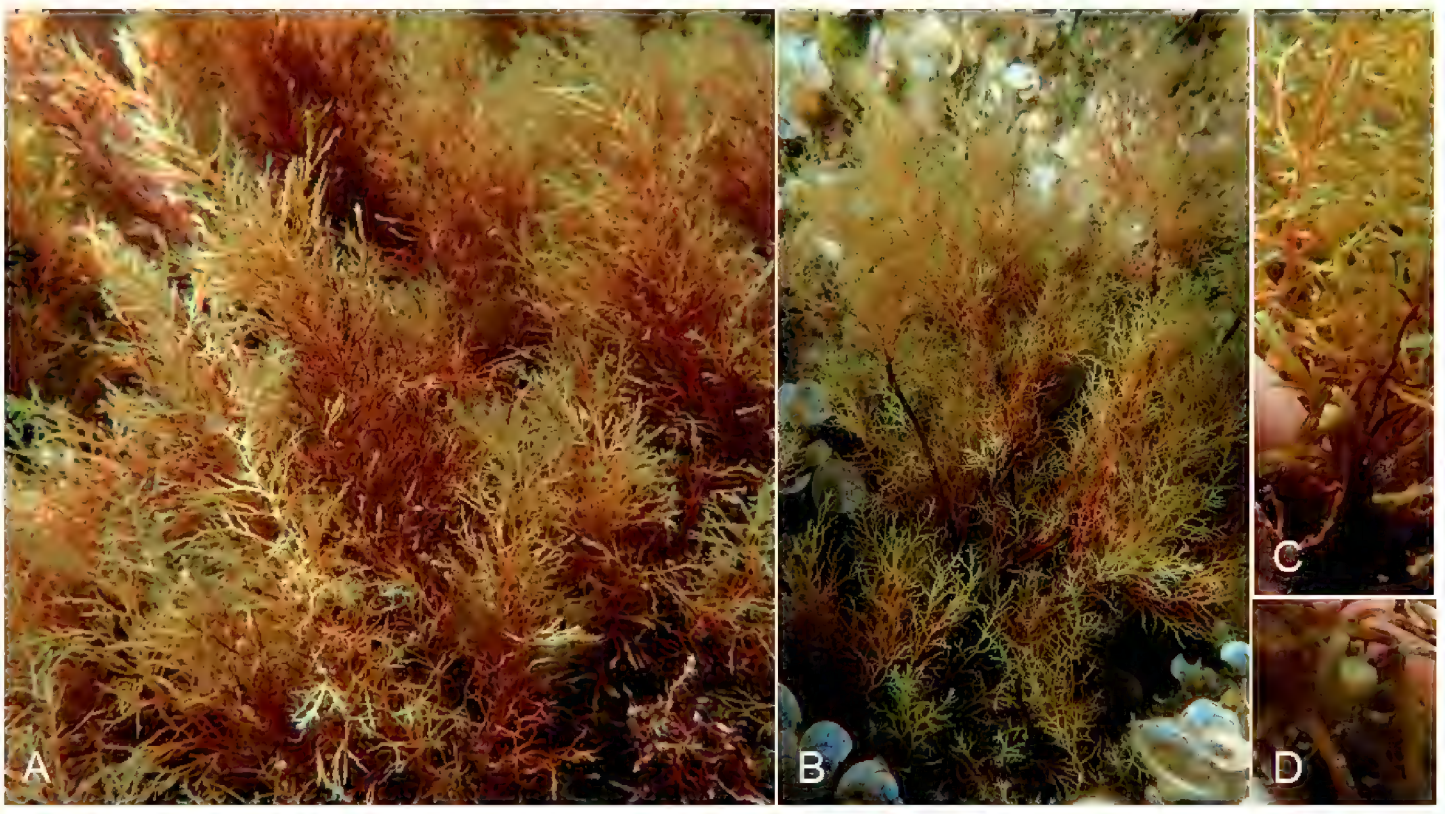

Figure 10. *Ericaria barbatula* **A** branches with fertile receptacles) **B** habit **C, D** prominent and smooth apex.

higher order branches are cylindrical. During the monitoring activities, this species was found fertile. The receptacles are borne on the apical parts of branchlets and are compact, tuberculate; they can bear 1–2 spinose appendages.

Habitat. *E. barbatula* was observed during snorkelling in shallow environments (from 0.5 to 3 m of depth) along sheltered and moderately exposed coasts at Bue Marino, Kattibuale, Martingana, Scauri, Kuddie Rosse and Arenella.

Distribution. Cyprus, Greece, Libya, Malta, Italy and Tunisia (Blanfuné et al. 2022).

Remarks. Comparing our data with the study by Alongi et al. (2004), this species appears to have expanded its distribution along the island since then. According to Neiva et al. (2022), this entity falls in the *Ericaria crinita* complex, which includes samples identified as *E. crinita*, *E. barbatula* and *E. giacconei* D. Serio & G. Furnari.

Ericaria balearica (Sauvageau) Neiva, Ballesteros & Serrão

Fig. 11A–D

Cystoseira balearica Sauvageau. Basionym.
Cystoseira brachycarpa var. *balearica* (Sauvageau) Giaccone. Synonyms.

Morphology of specimens from Pantelleria. This species is caespitose, with an irregular, spreading holdfast, from which several axes are issued. The axes are cylindrical and knotty due to the presence of basal stumps of the fallen branches. This species shows a dark blue-green iridescence *in situ*, especially in the apical parts of branchlets. The apices are not prominent and bear spinose appendages. Primary branches are cylindrical and are spinose only in the basal parts. Higher order branches are cylindrical

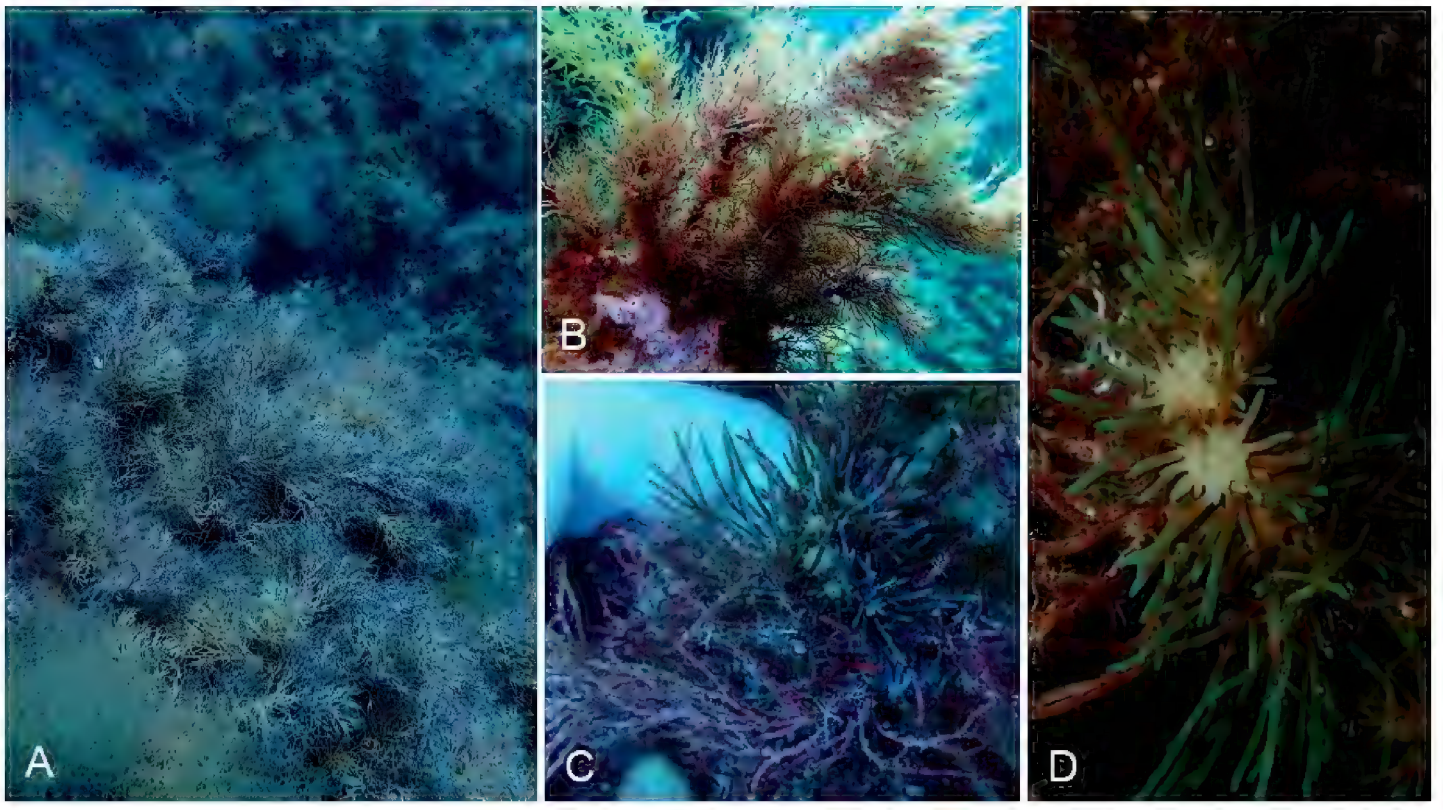

Figure 11. *Ericaria balearica* **A, B** habit **C, D** detail of not prominent apices with spinose appendages.

as well, but they are not spinose. During the monitoring activities, this species was not reproductive.

Habitat. *E. balearica* was observed during both scuba dives and snorkelling activities at Bue Marino, Punta Spadillo, Cala Tramontana, Cala Levante, Scauri, Grotte Sataria, Kuddie Rosse. In the Island of Pantelleria it is widely distributed from the upper to the lower infralittoral (from 0.5 to 28 m of depth).

Distribution. According to Neiva et al. (2022), this species is distributed in the Balearic Sea and the Island of Pantelleria.

Remarks. This species was reported from the island by Alongi et al. (2004) as *Cystoseira brachycarpa* J. Agardh. Recently, Neiva et al. (2022) concluded that *E. brachycarpa* (J. Agardh) Molinari & Guiry and *E. balearica* are two cryptic species with different biogeographical distribution.

Ericaria cf. *dubia* (Valiante) Neiva & Serrão

Fig. 12A–C

Cystoseira dubia Valiante. Basionym.

Morphology of specimens from Pantelleria. In the examined specimens, the holdfast could not be observed in detail because it was sunken in coarse gravel. The axes are creeping on the substrate and issue on the upper side erect primary branches in which two portions can be recognized: a cylindrical basal one and a flattened and ribbon-like upper one. Primary branches are distichous, without spinose appendages, with an entire margin and an evident midrib. During the monitoring this species was not found reproductive.

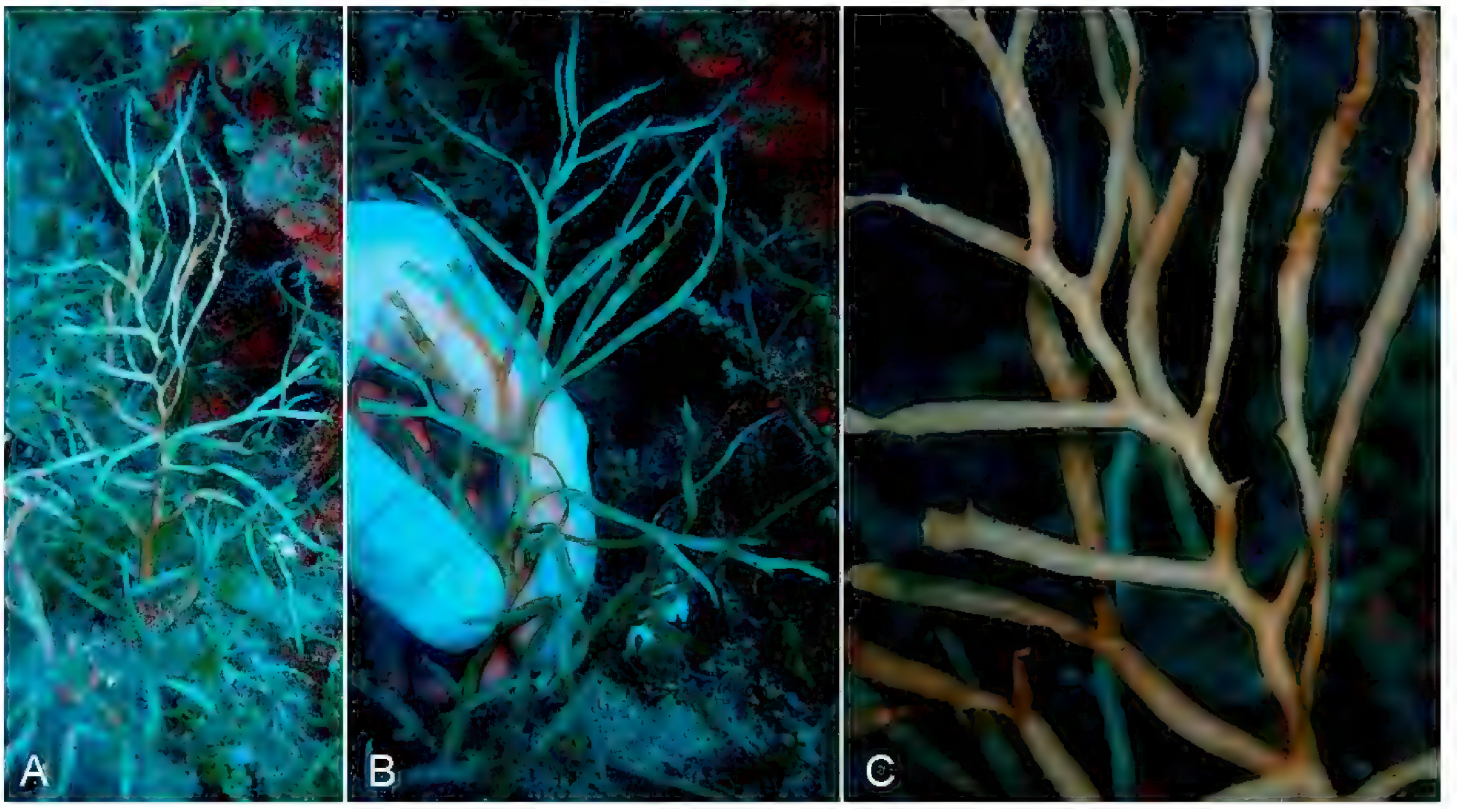

Figure 12. *Ericaria* cf. *dubia* **A, B** habit **C** detail of flattened branches with distichous disposal and an evident midrib.

Habitat. *Ericaria* cf. *dubia* was observed during scuba dives at Punta Spadillo and Cala Levante, at 40 and 35 m depth, respectively.

Distribution. This species is distributed in the Adriatic Sea, Greece, Italy, Syria, Tunisia, Turkey and Middle East (Blanfuné et al. 2022).

Remarks. The identification at species level was not certain because we did not manage to observe the holdfast, apex and receptacles of this entity.

Ericaria crinita (Duby) Molinari & Guiry

Fig. 13A–C

Cystoseira crinita Duby. Basionym.

Cystoseira granulata Schousboe, *Fucus crinitus* Desfontaines, *Carpodesmia crinita* (Duby) Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *E. crinita* is a caespitose species, adhering to the substrate by an irregular discoid holdfast, from which several cylindrical and knotted axes are issued. The apices are protruding and covered by spinose appendages. Primary branches are cylindrical, with a pyramidal habit. Higher order branches are cylindrical, thin, more or less twisted and usually devoid of spines. During the monitoring activities, this species was found fertile. Receptacles are borne on terminal branchlets; they are compact, cylindrical, swollen, single or once branched, usually without spiny appendages.

Figure 13. *Ericaria crinita* **A** habit **B** detail of receptacles **C** detail of prominent apex with spinose appendages.

Habitat. This species was observed during snorkelling activities at Martingana and Arenella, in shallow (0.5–3 m) and sheltered habitats.

Distribution. This species is widespread in the Mediterranean Sea and Canary Islands (Blanfuné et al. 2022).

Remarks. This species was found by Giaccone et al. (1972) in several sites of the island. Subsequently, it was not reported by Alongi et al. (2004). Our record seems to suggest that *E. crinita* might be in a phase of recovery and expansion on the island. According to Neiva et al. (2022), this entity is part of the *Ericaria crinita* complex, which includes samples identified as *E. crinita*, *E. barbatula* and *E. giacconei*.

Ericaria sedoides Neiva & Serrão

Fig. 14A–C

Fucus sedoides Desfontaines. Basionym.
Fucus ericoides var. *sedoides* Turner, *Cystoseira sedoides* C. Agardh. Synonyms.

Morphology of specimens from Pantelleria. *E. sedoides* is a non-caespitose species, adhering to the substrate by a discoid holdfast from which a single cylindrical, trunk-like axis originates. This species is easily recognized by its typical brush-like habit. The axis is very thick and usually poorly branched. The apex is not very prominent and usually is covered by branches that form a compact terminal rosette. All branches are covered by spinose appendages, which are slender, bifid and uniformly distributed along the branches. Primary branches are short (1–3 cm) and their attachment is perpendicular to the

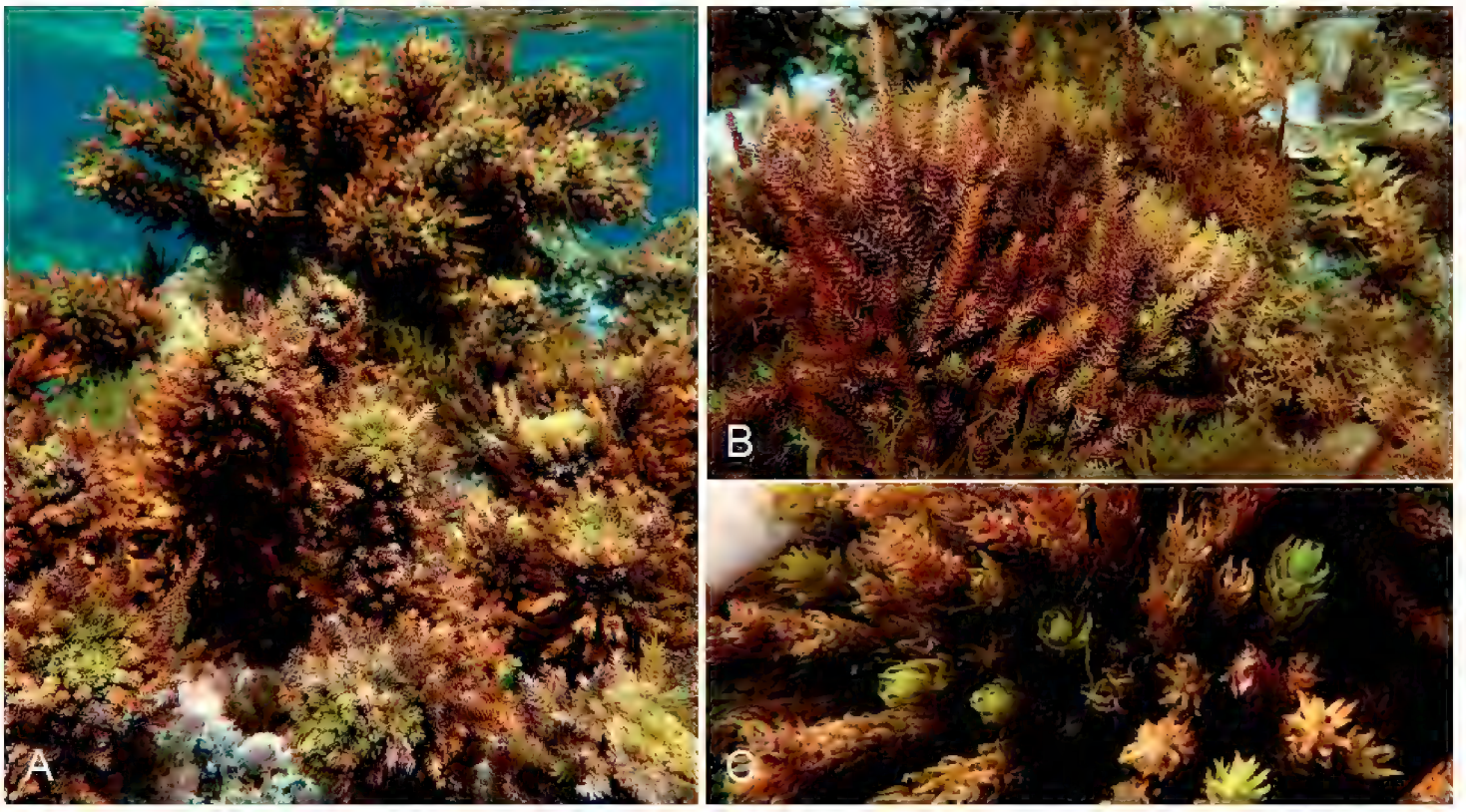

Figure 14. *Ericaria sedoides* **A, B** habit **C** not prominent apex, covered by the branches.

main axis. Secondary branches are usually simple and do not reach the top of primary branches. During the monitoring activities, this species was not found fertile.

Habitat. This species was observed during snorkelling activities in the upper infralittoral (0–1 m) along semi-exposed and exposed coasts at Bue Marino, Kuddie Rosse and Arenella.

Distribution. *E. sedoides* is endemic to Algeria, Tunisia and the Island of Pantelleria (Blanfuné et al. 2022).

Gongolaria barbata (Stackhouse) Kuntze

Fig. 15A–D

Abrotanifolia barbata Stackhouse. Basionym.

Cystoseira barbata var. *hoppei* (C. Agardh) J. Agardh, *Cystoseira barbata* f. *hoppei* (C. Agardh) Woronichin, *Cystoseira hoppei* C. Agardh, *Fucus barbatus* Goodenough & Woodward, *Treptacantha barbata* (Stackhouse) Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *G. barbata* is a non-caespitose species, attached to the substrate by a small discoid holdfast, from which a single trunk-like, cylindrical axis is issued. The apex is smooth and prominent, protruding above the insertion of primary branches. These are cylindrical, while higher order branches are filiform and can bear aerocysts, either isolated or in chains. During the monitoring activities, this species was found fertile. Receptacles are borne on terminal branchlets, are compact, single, cylindrical-lanceolate or spindle-shaped, sometimes with a terminal spine, and pedicellate when they grow over an aerocyst.

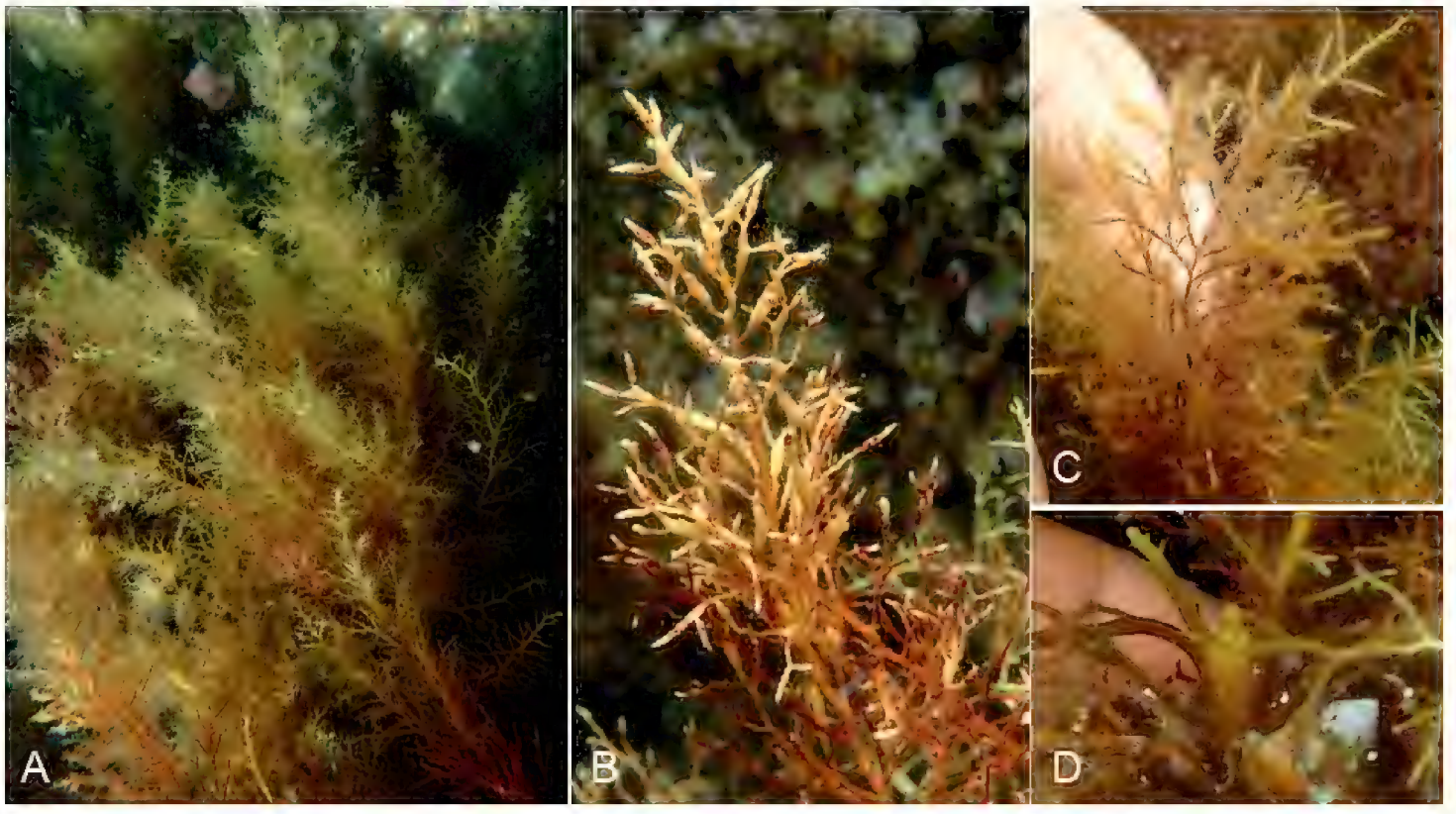

Figure 15. *Gongolaria barbata* **A** habit **B** detail of aerocysts surmounted by receptacles **C** detail of spindle-shaped receptacles **D** Detail of prominent and smooth apex.

Habitat. During the monitoring activities, this species was observed in the upper infralittoral (0.5–2 m) in sheltered habitats (such as rock pools) at Kuddie Rosse and Arenella.

Distribution. *G. barbata* is widely distributed in the Mediterranean Sea, and it also known from the Atlantic Ocean, in the Canary Islands and Savage Islands (Blanfuné et al. 2022).

Remarks. This species had not been reported from the island before.

Gongolaria elegans (Sauvageau) Molinari & Guiry

Fig. 16A–C

Cystoseira elegans Sauvageau. Basionym.
Treptacantha elegans (Sauvageau) Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *G. elegans* is a non-caespitose species, attached to the substrate by a robust discoid holdfast. The axis is short, trunk-like and cylindrical, not or poorly branched. The apex is spinose and not prominent. With the surrounding tips of primary branches, usually it forms a typical spinose rosette. Primary branches are cylindrical and bare in their basal parts. Higher order branches are cylindrical and covered with bifid spinose appendages. This species bears spinose and ovoid tophules, grouped along the axis. During the monitoring activities, this species was not found fertile.

Habitat. *G. elegans* was observed during both snorkelling activities and scuba dives, from the upper to the middle infralittoral (from 1 to 15 m) in moderately exposed/

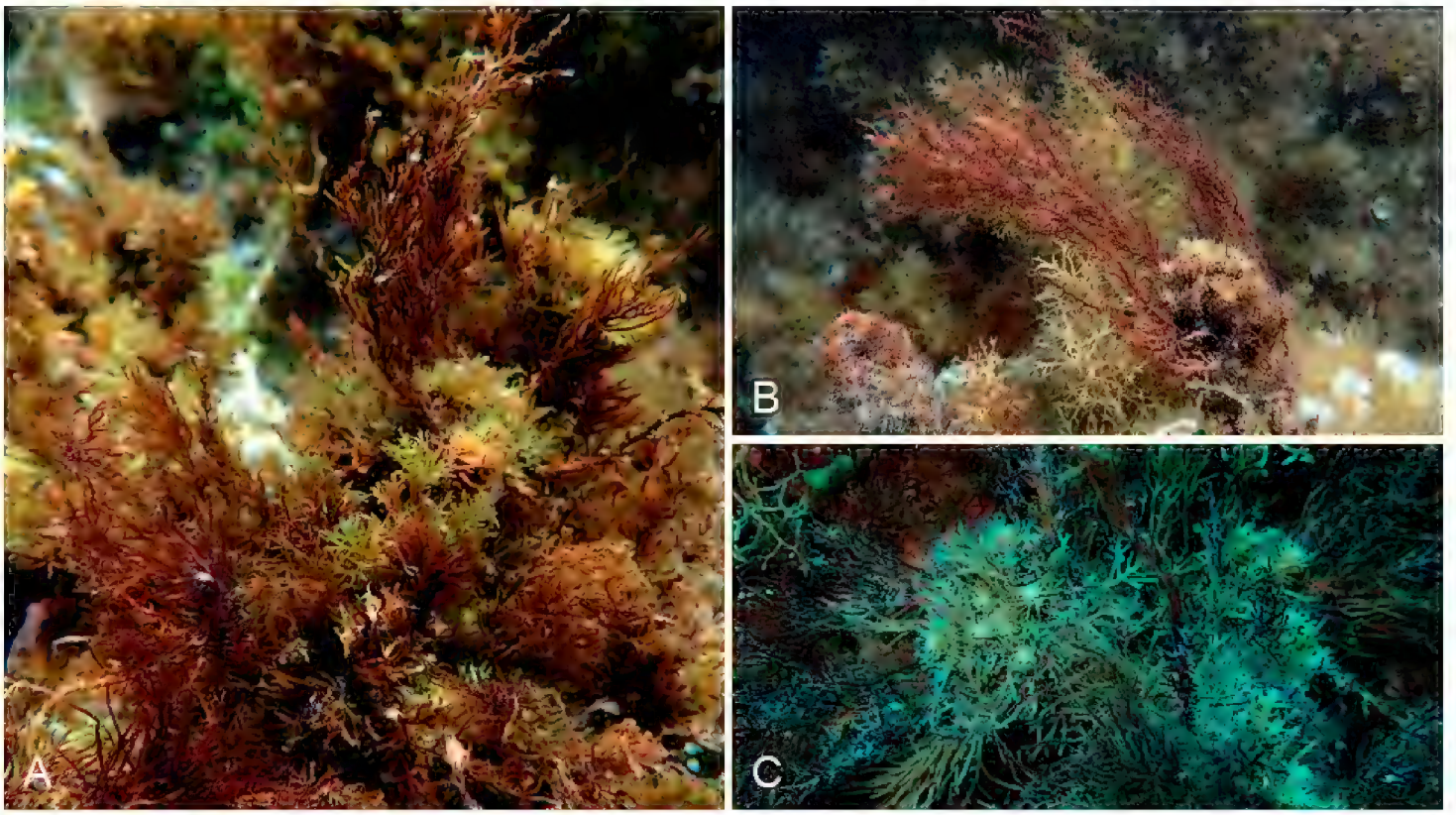

Figure 16. *Gongolaria elegans* **A, B** habit **C** detail of the apex surrounded by the buds of primary branches, which form a wide spinose rosette.

exposed waters at Kattibuale, Punta Spadillo, Gadir, Cala Tramontana, Cala Levante, Martingana, Kuddie Rosse and Arenella.

Distribution. This species is distributed in Spain, France, Morocco, Algeria, Tunisia, Italy, Adriatic, Greece, Cyprus and Turkey (Blanfuné et al. 2022).

Remarks. This species was found by Giaccone et al. (1972), but Alongi et al. (2004) did not record it. Our record suggests that *G. elegans* might be in phase of expansion on the island.

Gongolaria montagnei (J.Agardh) Kuntze

Fig. 17A–C

Cystoseira montagnei J. Agardh. Basionym.

Cystoseira spinosa Sauvageau, *Cystoseira adriatica* Sauvageau, *Phyllacantha montagnei* (J. Agardh) Kützing, *Treptacantha montagnei* (J. Agardh) Orellana & Sansón, *Treptacantha ballesterosii* Orellana & Sansón. Synonyms.

Morphology of specimens from Pantelleria. *G. montagnei* is a non-caespitose species, fixed to the substrate by a robust discoid holdfast. The axis is trunk-like and cylindrical, unbranched or poorly branched. The apex is spinose and not prominent. Primary branches are cylindrical and bear numerous sparse bifid or multifid spinose appendages. Secondary branches are shorter and less branched, with divaricate and bifid spinose appendages. This species has oblong and spinose tophules. During scuba

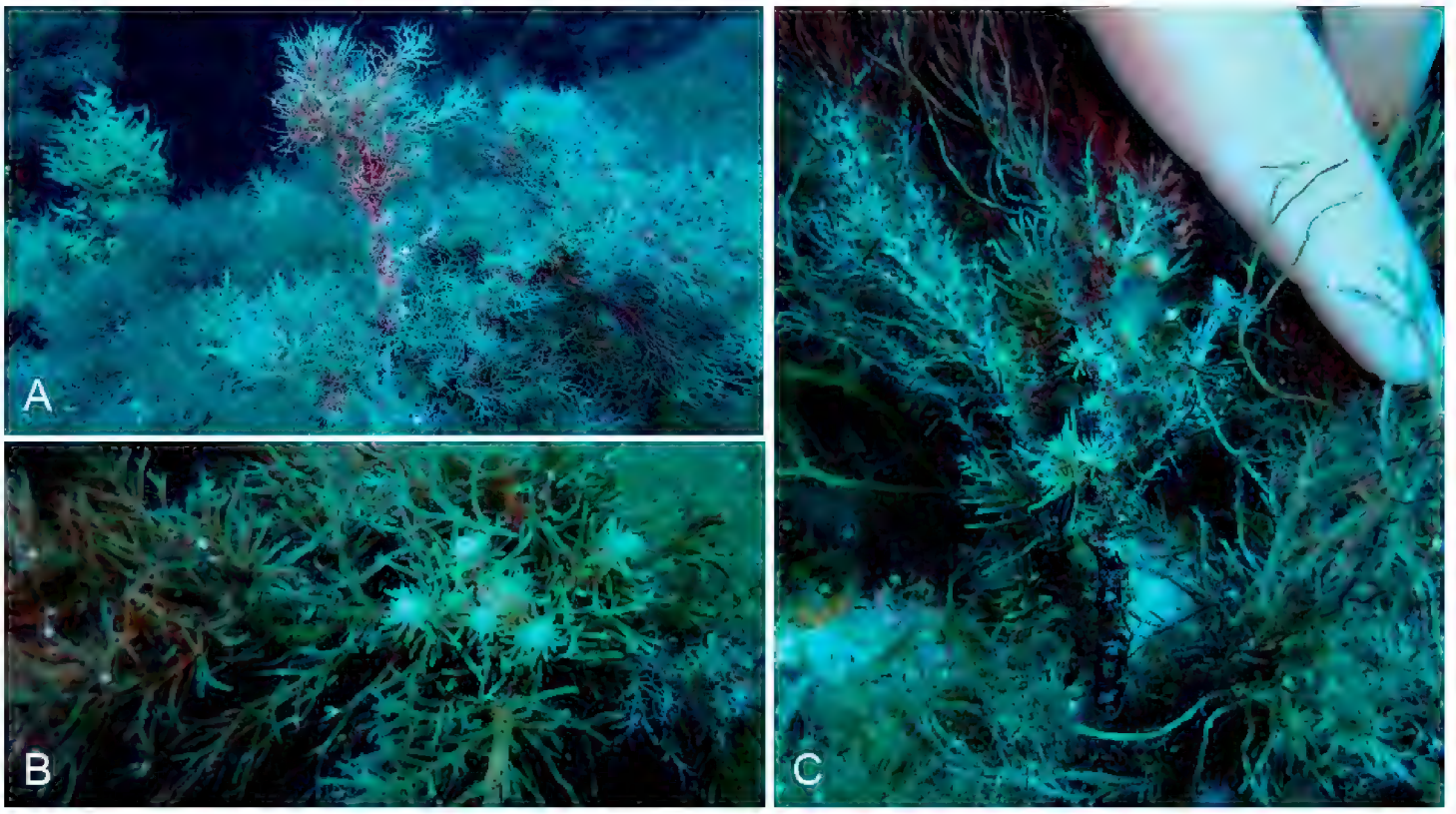

Figure 17. *Gongolaria montagnei* **A** habit **B** detail of not prominent and spinose apex **C** preliminary appearance of new primary branches from tophules.

dives, we observed new primary branches arising from tophules. During the monitoring activities, this species was not found fertile.

Habitat. This species was observed during scuba dives at Punta Spadillo, Cala Levante and Cala Tramontana, in the middle-lower infralittoral (from 8 down to a depth of 22 m).

Distribution. *G. montagnei* is widely distributed in the Mediterranean Sea (Blanfuné et al. 2022).

Gongolaria montagnei var. *compressa* (Ercegovic) Verlaque, Blanfuné, Boudouresque & Thibaut

Fig. 18A–C

Cystoseira adriatica subsp. *compressa* Ercegovic. Basionym.

Cystoseira adriatica subsp. *compressa* Ercegovic, *Cystoseira platyramosa* Ercegovic, *Cystoseira adriatica* subsp. *intermedia* Ercegovic, *Cystoseira adriatica* var. *intermedia* (Ercegovic) Giaccone, *Cystoseira spinosa* var. *compressa* (Ercegovic) Cormaci, G. Furnari, Giaccone, Scammacca & D. Serio, *Cystoseira montagnei* var. *compressa* (Ercegovic) M. Verlaque, Blanfuné, Boudouresque, Thibaut & Sellam. Synonyms.

Morphology of specimens from Pantelleria. This form is non-caespitose, adhering to the substrate by a discoid holdfast. The axis is trunk-like, simple, and usually shorter than in the autonymous form. All branches are flattened, with an alternate arrangement. They have serrated edges and a midrib. Spinose appendages can be present in

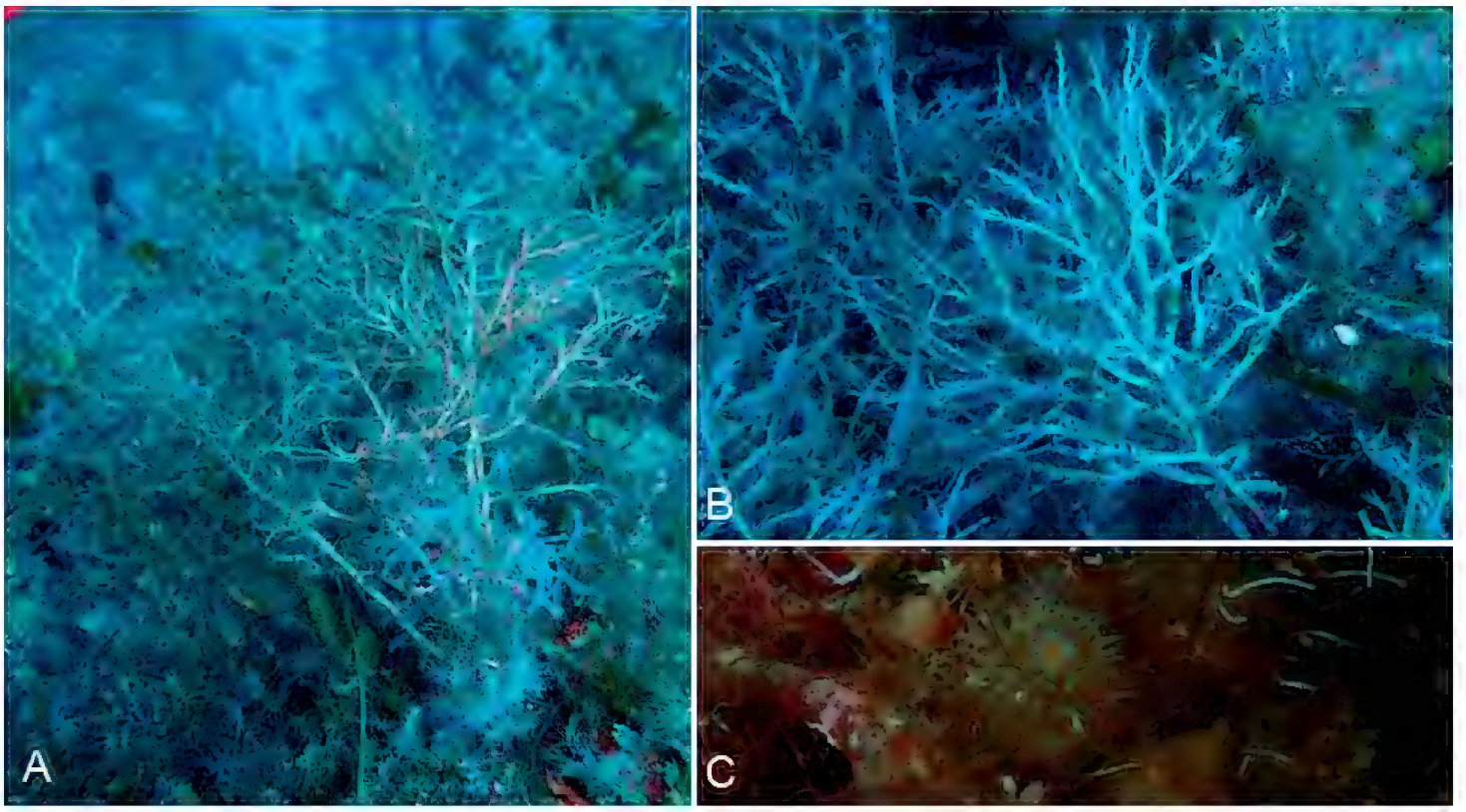

Figure 18. *Gongolaria montagnei* var. *compressa* **A** habit **B** flattened branches with midrib **C** detail of spinose tophules.

the apical parts of secondary branches. The tophules are borne near the base of the axis, oblong and spinose. During the monitoring activities, this form was not found fertile.

Habitat. *G. montagnei* var. *compressa* was observed during scuba dives at Punta Spadillo, Cala Levante and Cala Tramontana. In these sites, it grows in the lower infralittoral/circalittoral (from ca. 26 to 35 m of depth), on bottoms largely covered by detritus and subject to unidirectional currents.

Distribution. *G. montagnei* var. *compressa* is known from Spain, France, Italy, Adriatic, Greece, Libya and Turkey (Blanfuné et al. 2022).

Remarks. This seaweed was reported by Alongi et al. (2004) with a very limited coverage at Cala Levante. Therefore, it might currently be in a phase of increase.

Sargassum cf. *acinarium* (Linnaeus) Setchell

Fig. 19A, B

Fucus acinarius Linnaeus. Basionym.

Fucus acinarius S. G. Gmelin, *Fucus linariifolius* Turner, *Fucus linifolius* Turner, *Sargassum linifolium* C. Agardh, *Sargassum linifolium* f. *gibraltica* Grunow, *Sargassum vulgare* var. *linifolium* (C. Agardh) Zanardini. Synonyms.

Morphology of specimens from Pantelleria. *Sargassum* cf. *acinarium* is attached to the substrate by small discoid holdfast. Primary branches are cylindrical and knotty. Foliaceous branches are narrow (ca. 0.5–1 cm) with an evident midrib, acute apex and denticulate or entire margin. This species has spherical aerocysts with a cylindrical pedicel. During the monitoring, some specimens showed receptacles.

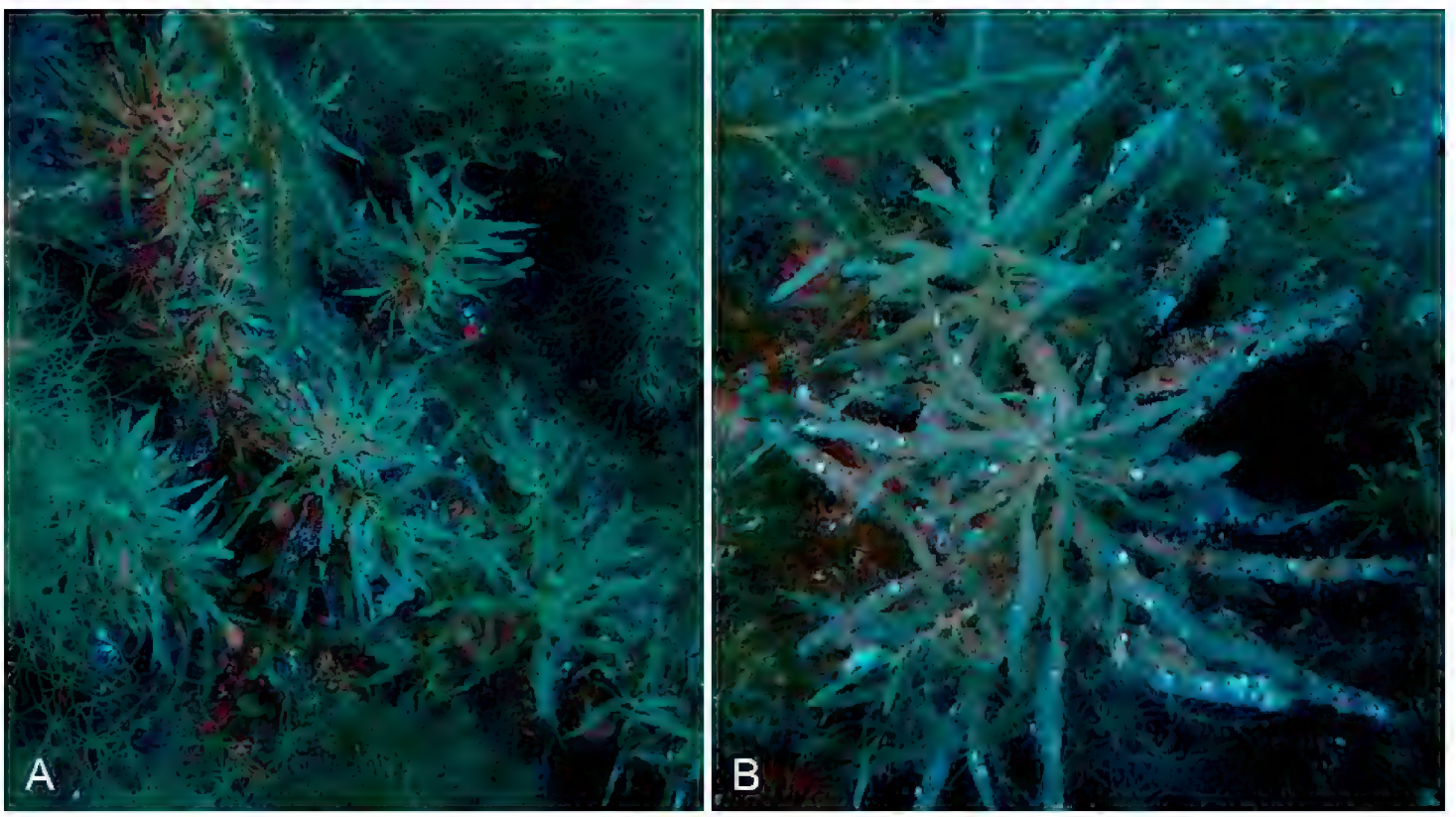

Figure 19. *Sargassum* cf. *acinarium* **A** habit **B** narrow foliaceous branches with an evident midrib.

Habitat. *S.* cf. *acinarium* was observed during scuba dives at Punta Spadillo, Cala Tramontana and Cala Levante, in the lower infralittoral/circalittoral (from 28 to 45 m).

Distribution. This seaweed is distributed in the north-western Atlantic (from Spain to Guinea-Bissau) and in the Mediterranen Sea (Blanfuné et al. 2022).

Remarks. The identification at species level was not certain because it was not possible to collect the receptacles of this entity.

Sargassum vulgare C. Agardh

Fig. 20A–C

Sargassum vulgare C. Agardh, nom. illeg. Basionym.
Fucus salicifolius S. G. Gmelin, *Sargassum megalophyllum* Montagne, *Sargassum coarctatum* Kützing, *Sargassum vulgare* var. *megalophyllum* (Montagne) Vickers. Synonyms.

Morphology of specimens from Pantelleria. *S. vulgare* is attached to the substrate by a small discoid holdfast. The axis is cylindrical and short. Primary branches are cylindrical and smooth or knotty, bearing sparse secondary branches with distichous-alternate arrangement. Foliaceous branches are abundant, lanceolate, with an evident midrib and serrate or wavy margins. The aerocysts are spherical, with a short cylindrical or flattened pedicel. During the monitoring this species was found fertile. The receptacles are fusiform or warty, simple or bifid, borne at the top of a short sterile, cylindrical and branched pedicel.

Habitat. *S. vulgare* was observed both during the snorkelling activities and scuba dives in all examined sites, from the upper infralittoral to the lower infralittoral (from 1 to 25 m) and in both sheltered and wave-exposed habitats.

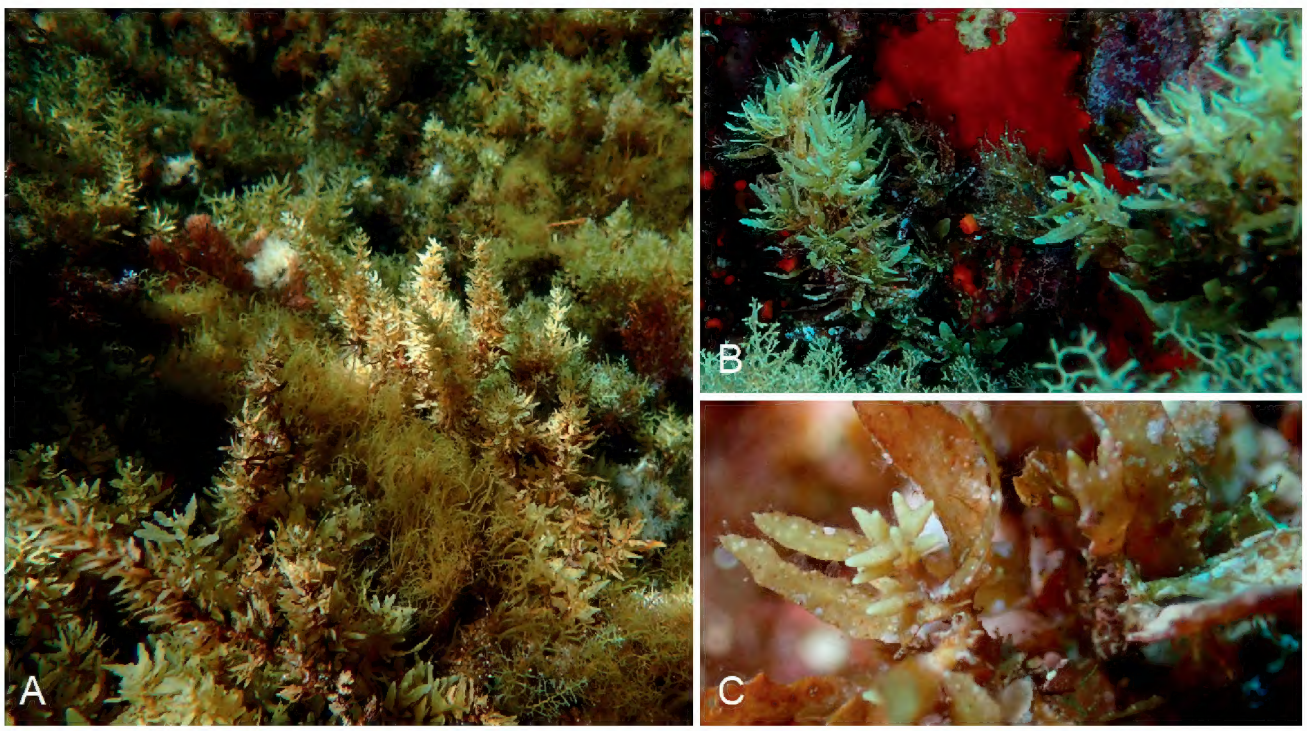

Figure 20. *Sargassum vulgare* **A, B** habit **C** detail of warty receptacles on a short pedicel.

Distribution. *S. vulgare* is widely distributed in the Atlantic Ocean and in the Mediterranean Sea (Blanfuné et al. 2022).

Remarks. Together with *C. compressa* and *E. amentacea*, this species was among the most common fucalean seaweeds along the coasts of the island.

Discussion

The present study allowed to provide an assessment of the current presence and distribution of *Cystoseira* s.l. and *Sargassum* species along the Island of Pantelleria, approximately 20 years after the most recent study on the marine flora of this island. The monitoring activities unraveled the occurrence of 19 taxa: seven belonging to *Cystoseira*, six to *Ericaria*, four to *Gongolaria*, and two to *Sargassum*. Unfortunately, due to the adverse sea conditions it was possible to carry out only a low number of scuba dives, thus this did not enable us to make a more accurate identification of *Sargassum* cf. *acinarium* and *Ericaria* cf. *dubia*. Moreover, the recent taxonomic and biogeographic revision of *Cystoseira* s.l. species demonstrated the necessity to combine morphological studies with genetic analyses, to reveal the possible existence of new entities or cryptic species (Neiva et al. 2022). This is the case of *C. pustulata*, which had previously been identified by some authors as *C. humilis*, but Neiva et al. (2022) highlighted that these are two separate species with well-defined and distinct biogeographical ranges. Neiva et al. (2022) analysed genetically many samples from the island of Pantelleria, but for other taxa additional studies based on molecular analyses should be carried out in the near future.

Comparing these data with the previous studies by Giaccone et al. (1972) and Alongi et al. (2004), we can confirm that most of the species found by these authors are still present on the island. However, we observed an important difference among the species reported by Giaccone et al. (1972) and those found by Alongi et al. (2004).

Indeed, Alongi et al. (2004) did not record some lower infralittoral/circalittoral species documented by Giaccone et al. (1972). In this study, deep-water species such as *C. foeniculacea* f. *latiramosa*, *G. elegans*, *G. montagnei*, *G. montagnei* v. *compressa* and *Sargassum* cf. *acinarium* were detected again about fifty years after the study of Giaccone et al. (1972). Moreover, we noted the presence of *Ericaria* cf. *dubia*, a species previously not documented for Pantelleria. This might indicate a possible natural recovery trend for these Fucales in the island, similar to what was observed at the Medes MPA (Spain) and at Ustica MPA (Italy), where there was a gradual recovery of *Cystoseira* s.l. populations at ca. 10–20 years after their disappearance (Bonaviri et al. 2009; Hereu and Quintana 2012; Sala et al. 2012). As suggested by Gianni et al. (2013), this progressive recolonization can happen thanks to the existence of fragmented reproductive populations in scattered refuge areas, even if at low densities. Therefore, it is likely that over the years it has occurred a gradual expansion of residual populations, survived in refuge sites in the Island of Pantelleria, which could be overlooked in previous surveys.

These deep species could be seriously impacted by the intense fishing activity carried out around the island, which could harm the populations through trawling or anchoring. Therefore, to guarantee a long-term conservation of these fucalean species, it would be helpful to establish a marine protected area in the Island of Pantelleria. Indeed, the marine environment of this island is currently not subjected to any kind of environmental protection, although a proposal to establish a marine protected area was forwarded approximately 20 years ago (Picchetti et al. 2010).

Recently, we (Lombardo and Marletta 2023) also reported a high potential diversity of marine Heterobranchia in the waters of Pantelleria. Therefore, we argue that it would be recommendable to establish a zonation of the island and regulate the anthropic activities, in order to preserve the high biodiversity of the Island of Pantelleria.

Acknowledgements

The authors wish to thank Prof. Fabio Rindi for his interesting and valuable comments and suggestions.

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